REPORT OF CHEMICAL DIVISION.

FEBRUARY 1, 1889.

SIR: I have the honor to submit herewith a statement of the work done in the Chemical Division during the past year.

Respectfully,

H. W. WILEY,
Chemist.

Hon. NORMAN J. COLMAN,
Commissioner of Agriculture.

ORGANIZATION AND EQUIPMENT OF THE DIVISION.

The necessity for a new building for laboratory purposes, as set forth in my last annual report, still continues. There are many chemical operations needful in agricultural investigations which can not be undertaken at all with our present facilities, or only imperfectly. Light and ventilation in the working rooms are bad and the location of the laboratory in the basement continues to be a source of grave discomfort to the other employés of the Department.

During the year the Division met with a sad loss in the death of Mr. N. J. Fake, on the 11th of August, by accidental drowning. On certification from the Civil Service Commission Mr. E. A. von Schweinitz has been appointed to the vacancy. The staff of the Division now comprises the following names:

H. W. Wiley, chemist.
C. A. Crampton, assistant chemist.
G. L. Spencer, assistant chemist.
E. A. Knorr, assistant in laboratory.
T. C. Trescot, assistant in laboratory.
Hubert Edson, assistant in laboratory.
E. A. von Schweinitz, assistant in laboratory.
John Dugan, assistant in laboratory.
K. P. McElroy, assistant in laboratory.
Oma Carr, assistant in laboratory.
J. L. Fuelling, assistant in sugar work.
M. S. Tidd, stenographer.
Martin Johnson, laborer.

MISCELLANEOUS ANALYSES.

SAMPLES OF MINERALS, ORES, ROCKS, ETC., SUBMITTED FOR ANALYSIS.

From the Hon. J. H. Blount, House of Representatives. Sample of metal, found to be pure tin.

From J. A. C. Blackburn, War Eagle Mills, Ark. A sample of limestone, with fragments of quartz and particles of iron pyrites. No value.

Sent by G. I. Baldwin, Hunlock Creek, Pa. A specimen of sandstone with particles of mica. This might prove to be a valuable building stone if found in quantity.

From the Hon. P. B. Plumb, U. S. Senate. A sample of ore which assayed 8.5 ounces of silver per ton.

From John F. Miller, Hagerstown, Md. A specimen consisting chiefly of carbonate of lime.

From the Hon. S. W. Peel, House of Representatives. A sample of red hematite, a valuable iron ore.

From J. T. Kale, Newcastle, Va. A specimen of calcite.

From Miss Ida Hays, Redington, Nebr. A sample of mica.

From the Hon. J. H. O'Neall, House of Representatives. A sample of mineral, largely carbonate of lime.

From the Hon. Charles T. O'Ferrall, House of Representatives. Six samples of minerals, as follows: No. 1, chiefly silicates; No. 2, galena, a valuable lead ore when occurring in quantity; No. 3, iron ore; No. 4, asbestos; this might prove valuable if found in sufficient quantity; No. 5, specimen of clay, of no special value; No. 6, micaceous rock, of no special value.

Sent by the Hon. F. M. Cockrell, U. S. Senate. A sample of ore, largely galena, a valuable source of lead.

Sent by the Hon. P. B. Plumb, U. S. Senate. Seven samples of magnetite which were analyzed with the following results:

No. of sample.	Oxide of iron.	Representing metallic iron.	Silica.	Phosphorus.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
1	69.63	50.42	18.04	....
2	88.71	64.24	12.38	....
3	62.42	45.20	25.27	....
4	81.89	59.30	13.31	Trace.
5	87.64	63.46	12.50	.28
6	60.24	45.62	33.50	Trace.
7	80.91	62.21	8.10	.14

Sent by the Hon. P. B. Plumb, U. S. Senate. A sample of coal which gave the following analytical data:

Moisture	.52
Volatile combustible matter	3.16
Fixed carbon	56.54
Ash	25.73
Sulphur	14.20
	100.15

This coal is not suitable for metallurgical purposes on account of the large quantity of ash and sulphur.

Sent by Miss Lottie Randaugh, Bloserville, Pa. A sample of oxide of iron.

From the Hon. J. M. Berry, U. S. Senate. Two samples of carbonate of lime, valuable if found in quantity. Also an iron ore containing 27.67 per cent. of iron.

Sent by the Hon. J. R. Brown, House of Representatives. A sample of iron ore containing 25.62 per cent. of iron. This sample and the above are hardly rich enough to make them available for the manufacture of iron.

From the Hon. S. W. Peel, House of Representatives. A sample of mineral of no value.

From J. E. Wiley, Macon, Ga. Two samples of mineral consisting chiefly of the silicates of iron and alumina.

From Israel Shafer, Richlandtown, Pa. A sample of slate rock with particles of pyrites. No value.

From R. A. Ormdorff, Van Buren Furnace, Va. A sample supposed to be coal, proved to be slate rock of no value.

From Mrs. E. F. Whitney, Munroe, Tenn. A sample of iron pyrites.

From W. P. Newman, Coffman, Mo. A specimen of red hematite.

From Ed. Riddill, Coxburgh, Miss. A sample of iron pyrites.

From W. F. White, Dunedin, Fla. Sample of quartz with mica.

From Leak and Selph, Orange Heights, Fla. A specimen of kaolin of good quality.

From John Street, Calamine, Ark. A sample of hematite, with much silica and a trace of phosphorus; no special value.

A sample of galena which might be valuable if occurring in quantity.

From J. M. Mohr, Passer P. O., Pa. A specimen of pectolite, essentially a silicate of lime and soda, of no commercial value.

From W. P. Newman, Coffman, Mo. A specimen of gneiss with a little iron ore; a specimen of crystallized carbonate of lime, neither of which possesses any commercial value.

From Chas. S. Sterner, Coopersburgh, Pa. A specimen of silicate of the following composition:

	Per cent.
Silica	56.69
Water	18.68
Alumina	17.97
Lime	5.80
Undetermined	.86
	100.00

It has no particular value.

From F. K. DeWitt, Graysville, Va. A sample of hematite.

From E. J. Joyner, Flag Pond, Va. A good specimen of limestone.

From Chas. Brodtman, Cape Girardeau, Mo. A sample of gypsum which on analysis gave the following data:

	Per cent.
Sulphate of lime	86.94
Carbonate of lime	6.16
Iron, alumina, etc	1.84
Moisture	5.06

SAMPLES OF FERTILIZERS, FERTILIZING MATERIALS, MARLS, ETC.

Sent by James Walker, Darien, Ga. A sample of mineral containing 8.81 per cent. of phosphoric acid; enough to make it of some value for manufacturing a fertilizer.

Sent by B. Rosenfeld, Mimbres, N. Mex. A sample of mineral which was tested for phosphoric acid, a trace of which was found; not enough, however, to make it available as a fertilizer.

Sent by E. W. Stump, Tombstone, Ariz. A sample of soil containing 4.74 per cent. of organic matter.

From J. H. Williams, Accokeek, Md. Two samples of marl, one of which contained a trace of phosphoric acid. Neither sample of any value.

From W. L. Gilbert, Ocean Springs, Miss. A sample containing a large quantity of lime.

From Julius Becker, Springerville, Ariz. Sample of gypsum.

From Mrs. Seton Lyles, Collington, Md. A sample of phosphate rock; of no value as a fertilizer.

From G. A. Bacon, U. S. Department of Agriculture. A sample of rock supposed to contain phosphoric acid, none of which was detected.

From H. S. Addison, New Orleans, La. A sample of rice-chaff ash containing of phosphoric acid .71 per cent., of little value as a fertilizer.

From W. Lee White, Pension Office. A sample of marl containing phosphoric acid, .11 per cent.; nitrogen, .05 per cent. Of no value as a fertilizer.

From H. C. Perkins, Llewellyn, Oregon. A sample of stone submitted for valuation as a fertilizer; no phosphoric acid was found.

From E. T. Peters, U. S. Department of Agriculture. A sample of clay containing too much sand to make it useful for a potter's clay.

From Barthelson and Fellanders, Sanford, Fla. A very poor sample of fertilizer, containing only 1 per cent. of phosphoric acid and .51 per cent. of potash.

From O. H. Kelley, Carrabelle, Fla. A sample of marl containing .12 per cent. of phosphoric acid.

From H. C. Perkins, Llewellyn, Oregon. A sample of marl containing only a trace of phosphoric acid, of no value as a fertilizer.

From Edward Ward, Pineville, Wis. A sample of marl containing .6 per cent. of phosphoric acid.

From the Rev. Carlisle P. B. Martin, Waverly, Tex. A sample of clay highly colored by oxide of iron.

From H. G. Hanna, Pembroke, Ky. A sample of limestone of fine texture. If

available in quantity it might make a good building material or be valuable for the manufacture of lime.

From G. H. Klippinger, Cherryville, Pa. A sample supposed to be a fertilizer, containing:

	Per cent.
Ammonia	.39
Potash	.06
Phosphoric acid	1.56

Almost worthless as a fertilizer.

From G. A. Grover, Horace, Dak. Analysis of sample of clay :

	Per cent.
Alumina	33.39
Iron FeO	5.49
Lime	3.96
Silica	48.97
Phosphoric acid	.05
Alkalis	Trace.
Organic matter	15.44
Moisture	5.97

From H. M. Smith, Lenah, Va. A sample of rock of no value.

From Joseph H. Key, Leonardstown, Md. A sample of green sand containing .47 per cent. of phosphoric, a trace of iron, and no potash. Of little value as a fertilizer.

From the Hon. J. M. Allen, H. R. A sample supposed to be suitable for the manufacture of cement. It was a mixture of limestone and sandstone, not exhibiting the proper hardening qualities.

From James M. Michael, Barnhart's Mills, Pa. A sample supposed to be a marl; was found to be a clay of no fertilizing properties whatever.

SAMPLES OF SORGHUM CANES, SUGAR BEETS, AND SIRUPS.

Sent by C. W. Wood, Hertford, N. C., two samples of sorghum cane:

	Amber.	Orange.
	Per cent.	*Per cent.*
Total solids	14.10	13.70
Sucrose	6.40	6.19
Glucose	4.97	(*)

*Not determined.

This cane does not appear to be quite ripe; would make a good sirup, but is unfit for sugar-making purposes.

Sent by David Cox, Hertford, N. C., two samples of sorghum cane:

	Early Orange.	Late Orange.
Juice..........per cent	56.17	54.57
Sucrose..........do	7.67	8.69
Glucose..........do	3.87	4.58
Specific gravity	1.050	1.061
Degrees Brix	13.00	14.70
Temperature....deg. C	22.5	22.7

Also a sample of Early Amber :

	Per cent.
Total solids	15.70
Sucrose	8.14
Glucose	6.62

Not suitable for sugar making purposes but would probably give a large yield of sirup.

Sent by W. B. Shaw, Shawborough, N. C., two samples of sorghum cane:

	No. 1.	No. 2.
Juice..........per cent..	....	58.88
Sucrose ....do....	11.05	7.07
Glucose ....do....	3.83	3.87
Specific gravity	....	1.05
Degrees Brix	16.4	12.20
Temperature....deg. C..	....	24.00

No. 1 is a rich cane for sugar-making purposes.

Sent by John Upton, Belcross, N. C., two samples of sorghum cane:

	Early Amber.	Early Orange.
Juice..........per cent..	56.80	55.20
Sucrose ....do....	12.28	7.94
Glucose ....do....	2.57	4.86
Specific gravity..........	1.06	1.05
Degrees Brix	16.10	13.60
Temperature....deg. C..	24.6	25.00

Sent by Harvey Terry, Terry's Manor, North Carolina, four samples of sorghum cane:

	Early Amber.	Late Orange.	Amber.
Juice..........per cent..	54.44	55.95	54.58
Sucrose ....do....	6.05	7.42	7.09
Glucose ....do....	5.23	4.00	4.37
Specific gravity	1.05	1.05	1.05
Degrees Brix	12.00	12.22	12.00
Temperature....deg. C..	24.70	23.00	23.00

No. 4 had undergone acid fermentation and analyzed as follows:

	Per cent.
Total solids..	16.30
Sucrose	7.57
Glucose	4.75

Sent by Densmore Bros., Red Wing, Minn., a sample of sorghum molasses:

	Per cent.
By direct polarization........................sucrose..	46.30
By invert polarization ....do....	49.16
Reducing sugars..	30.40

It is rich in sucrose and ought to yield a large crop of crystals if boiled to the proper density.

Sent by A. F. George, Ada, Minn., two samples of sugar beets:

	White beets.	Yellow beets.
Juice ....per cent..	59.66	69.47
Moisture ....do.....	89.99	89.45
Purity....................	60.27	59.44
Sucrose .... ..per cent..	6.69	5.41
Specific gravity	1.043	1.035
Degrees Brix............	11.10	9.10
Temperature .....Cent..	20°	22°

These are both below the average for sugar beets in this country.

Sent by C. W. Scarff, Grand Island, Nebr., two samples of sugar beets:

	Vilmorin.	White Imperial.
Total solids. per cent.	18.40	18.80
Sugar ....do....	15.38	15.75
Purity..............	83.59	83.77

These are very rich and capable of producing not less than 230 pounds of sugar per ton of beets.

Sent by William Juntgen, Kansas, Ill., a sample of sugar beet:

Total solids	per cent.	10.40
Sucrose	do	4.73
Purity		45.48

These beets are unfit for the manufacture of sugar.

Sent by W. C. Buderus, Sturgis, Dak., two samples of sugar beets:

	Pink beets.	White beets.
Total solids... per cent..	20.40	21.48
Sugar ....do.....	13.32	15.03
Purity co-efficient.......	65.29	69.97

A high percentage of sugar, but also a large quantity of total solids.

Sent by Hon. E. N. Morrill, House Representatives. Sample of sorghum molasses, too small a quantity for analysis.

Sent by H. S. Trescot, Pendleton, S. C. Two samples of sorghum sirup.

	No. 1.	No. 2.
	Per cent.	*Per cent.*
Moisture	21.48	28.60
Ash	2.76	1.92
Glucose	35 97	38.48
Sucrose	39.20	33.10

Sent by the Hon. F. M. Cockrell, U. S. Senate. A sample of molasses:

	Per cent.
Sucrose	42.00
Glucose	26.29
Moisture	28.13
Ash	2.63
Undetermined	.95

ANALYSES OF SAMPLES OF WATER.

From E. W. Deming, Conway Springs, Kans. Two samples of water: River water, 20.07 grains total solids per United States gallon. Well water, 12.52 grains total solids per United States gallon.

These waters are both excellent for technical purposes.

From H. L. Long, Walnut, Tex. A sample of water containing 201.88 grains of solids per gallon, comprised chiefly of sulphate of calcium and some chloride of sodium.

From Henry Peaslee, Georgetown, Tex. A sample of water containing 655.55 grains of solids per United States gallon. A partial quantitative analysis of the solid matter showed the following composition:

Sodic chloride	grains per United States gallon	194.77
Magnesia	do	26.88
Alumina	do	57.77

This water is unfit for drinking purposes.

Sent by H. B. Bicksler, Herndon, Va. A sample of water containing 19 grains of total solids per gallon, consisting of carbonates and sulphates of lime and magnesia, with organic matter, and traces of alkaline chlorides.

From W. H. Thomas, La Grange, Mo., a sample of water a complete analysis of which was made:

	Grains per United States gallon.
Sulphate of sodium	9.223
Chloride of sodium	320.607
Carbonate of potassium	6.174
Carbonate of sodium	.748
Carbonate of calcium	35.836
Carbonate of magnesium	20.532
Alumina	.093
Ferric oxide	Trace.
Silica	2.891
Total solids	396.104

From the Hon. J. N. Burnes, House of Representatives, a water containing 38.59 grains of solids per gallon, consisting of lime, magnesia, alumina, iron, and alkalis combined with sulphuric, carbonic, and hydrochloric acids and silica.

Sent by the Hon. C. T. O'Ferrall, House of Representatives, a sample of water containing 15.87 grains per gallon of solids, consisting of the same ingredients as the above sample.

From J. P. Eaton, Mapleville, Nebr., two samples of water. Water from 25-foot well contains 38.43 grains of solids per gallon; water from 91-foot well contains 20.07 grains of solids per gallon.

The composition of the solid matter is the same as in the two preceding samples.

From the Hon. Samuel Pasco, U. S. Senate, a sample of water, a complete analysis of which was made:

	Parts per million.
Oxygen required by organic matter	31.50
Free ammonia	.44
Albuminoid ammonia	.18
Nitrates	
Nitrites	Trace.
Total solids ... grains per gallon	167.50
Chlorine ... do	62.68

The solid matter consists of—

Lime ... grains per gallon	9.96
Magnesia ... do	3.01
Sodic chloride ... do	61.66
Soda ... do	5.88
Potassic chloride	Trace.
Sulphuric acid ... grains per gallon	9.27
Carbonic acid ... do	7.86
Silica ... do	.60
Iron and alumina	Trace.
Undetermined ... grains per gallon	1.74
	100.00

This is a mineral water and might prove to possess medicinal virtues.

MISCELLANEOUS SAMPLES.

From M. J. Albright, Rago, Kans. A sample of salt containing 98.86 per cent. of sodic chloride.

From Mrs. Jenkins, Washington, D. C. A sample of powders which was tested for bromides, chloral, and morphine, with negative results.

From Mrs. Grigsby, Washington, D. C. A sample of milk containing:

	Per cent.
Total solids	9.76
Fat	1.65
Albuminoids	3.09

This is a very inferior sample of milk, having been deprived of at least two-thirds of its cream.

From E. S. Stover, Albuquerque, N. Mex. A sample of cane, for valuation as a fodder:

	Per cent.
Albuminoids	3.68
Fat and oil	3.58
Alcohol extract	26.34
Crude fiber	13.35

It is deficient in nitrogenous principles, but might prove an acceptable change of diet for cattle.

Sent by D. J. Fair, Sterling, Kans. A sample of brine:

Specific gravity	1.1892
Total solids	25.09

In the dry substance there was found:

	Per cent.
Sodic cloride	91.95
Magnesia	1.86
Sulphuric acid	.89
Undetermined	5.30

Sent by R. F. Bond, Sterling, Kans., two samples of brine and two samples of salt:

	Brine 1.	Brine 2.	Salt 1.	Salt 2.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Total solid matter	27.51	27.07	90.33	94.98
Sodic chloride	26.18	24.65	86.63	90.45
Magnesia	.07	.49	.11	.08
Lime	Trace.	Trace.	.44	1.25
Sulphuric acid	.23	.42	.51	.78
Moisture	72.85	72.93	9.67	5.02
Undetermined	.67	2.51	4.64	2.45

Submitted by Professor Alwood, Department of Agriculture. An insect powder in which arsenic in quantity was found.

From the Hon. E. O. Graves, Superintendent of Bureau of Printing and Engraving. A sample of linseed-oil:

Specific gravity at 15.5° C	.9325
Percentage of iodine observed	152.00
Refractive index at 17.5° C	1.4785

No adulteration was discovered.

Sent by Nelson Page, Washington, D. C., a sample of rye flour supposed to have been sifted:

	Per cent.
Crude fiber	11.44
Starch	24.05

The sample resembles rye bran rather than flour, and has evidently been sifted.

From Dr. F. L. Kilbourne, U. S. Department of Agriculture. Two samples of linseed-oil cake:

	No. 1.	No. 2.
	Per cent.	*Per cent.*
Starch	20.78	19.18
Crude fiber	4.23	5.96
Moisture	8.38	7.84
Ash	5.79	5.72
Fat and oil	9.05	4.28
Alcohol extract	12.80	12.91
Albuminoids	31.69	38.69

From C. F. Hopkins, United States Department of Agriculture. Two samples of grapes.

	No. 1.	No. 2.
	Per cent.	*Per cent.*
Sucrose	6.99	3.75
Reducing sugars	9.53	10.54
Total sugars	16.52	14.29

From Prof. Cummings Cherry, Chicago, Ill. Specimen of palmetto root, stalk, and leaves.

	Root.	Stalk.	Leaves.
	Per cent.	*Per cent.*	*Per cent.*
Ether extract	.71	.49	2.79
Albuminoids	1.66	2.10	7.79
Crude fiber	45.85	46.30	50.22

SAMPLES ANALYZED FOR THE ASSOCIATION OF OFFICIAL AGRICULTURAL CHEMISTS.

Samples received from Prof. J. A. Meyers, chairman of committee on potash.

	By method of A. O. A. C.		By Lindo Gladding method.
	Per cent. KCl.	*Per cent.* KCl.	*Per cent.* KCl.
No. 1. Potassic chloride	85.04 85.16 85.06	84.83* 84.71* 84.08*	85.64 85.56
		Per cent. K_2O.	*Per cent.* K_2O.
No. 2. C. P. potassic sulphate	....	55.48 53.68	54.10 54.02 53.86
No. 3. Acid phosphate with potassic sulphate	....	13.70 13.82 13.89	13.62 13.72 13.78
No. 4. Calcined kainite	....	17.20 17.20 17.26	17.32 17.26 ....
No. 5	....	4.96 4.99	5.13 5.30

Analyses made by A. E. Knorr, except those marked *, which were made by Dr. C. A. Crampton.

Samples from Dr. W. J. Gascoyne, chairman of committee on phosphoric acid. Analyzed by A. E. Knorr:

	Moisture.	Phosphoric acid.
	Per cent.	*Per cent.*
No. 1. South Carolina phosphate	.76	28.16
No. 2. Tankage	6.44	14.23

	No. 3. Ammoniated superphosphate.	No. 4. Dissolved South Carolina phosphate.	No. 5. Dissolved Navassa phosphate.
	Per cent.	*Per cent.*	*Per cent.*
Moisture	14.06	9.33	8.25
Soluble phosphoric acid	6.74	10.63	6.78
Reverted phosphoric acid	1.59	3.31	7.94
Available phosphoric acid	8.33	13.94	14.72
Insoluble phosphoric acid	1.30	1.28	3.34
Total phosphoric acid	9.63	15.22	18.06

Samples from Prof. M. A. Scovell, chairman of committee on nitrogen. Analyses made by T. C. Trescot: No. 1. potassium nitrate C. P.; No. 2. cotton-seed meal; No. 3. sodium nitrate C. P., ammonium sulphate C. P., cotton-seed meal and acid phosphate; No. 4. sodium nitrate C. P., cotton-seed meal, muriate of potash and acid phosphate; No. 5. a mixed tankage of the trade.

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
	Per ct. N.	*Per ct. N.*	*Per ct. N.*	*Per ct. N.*	*Per ct. N.*
By soda-lime method	....	7.14	....	....	2.85
By Kjeldahl method	....	7.50	....	....	2.91
By Kjeldahl modified for nitrates	13.73	....	3.70	3.13	....
By Ruffle method	13.83	7.47	3.86	3.16	2.97

Sample received from Prof. Richard H. Gaines, chairman of committee on phosphoric acid. Analyzed by E. A. von Schweinitz and J. L. Fuelling:

	Schweinitz.			Fuelling.		
	No. 1.	No. 2.	No. 3.	No. 1.	No. 2.	No. 3.
Soluble phosphoric acid	....	10.72	6.63	....	10.72	6.74
Reverted phosphoric acid	....	2.13	1.90	....	1.92	1.80
Available phosphoric acid	....	12.85	8.53	....	12.64	8.54
Insoluble phosphoric acid	....	1.53	1.62 2.01	....	1.93	2.00
Total phosphoric acid	21.81	14.38	10.15	22.03	14.57	10.53

In connection with the investigation on the nature and causes of "peach yellows" carried on by the Division of Pathological Botany of this Department, a series of ash analyses of the different parts of the peach tree was made by A. E. Knorr. A full discussion of these analyses will be found in the special bulletin published by that division on this subject.

SWEET CASSAVA.*

(*Jatropha manihot* or Aïpi.)

About the middle of March, this year, I received from Mr. R. H. Burr, of Bartow, Fla., a package of cassava roots. These roots reached the Department in fine condition, being apparently as fresh as the day they were taken from the soil. After careful sampling and cleaning, a sufficient quantity of the roots was cut into thin slices and thoroughly dried. In a definite weighed portion, sampled as carefully as possible, the percentage of moisture was determined. The dried and powdered roots were preserved for future analysis. Owing to a press of other matter, this analysis was not made until the latter part of July and the first of August this year. Mr. Burr, in forwarding the roots, sent the following information concerning them:

The roots do not last long after digging, drying up or rotting. Since this variety of cassava is not the bitter or poisonous kind, it is generally known in Florida as the sweet cassava. The roots are fed to all kinds of stock in a fresh state, and are greatly relished. It has been sufficiently tested here to show its great value as a stock food. The yield under favorable conditions is astonishing. I have recently dug one plant of one year's growth, which weighed 50 pounds, being at the rate of more than 1,500 bushels to the acre. Eight hundred to 1,000 bushels per acre can be confidently reckoned on.

* Read by permission of the Commissioner of Agriculture at the Cleveland meeting of the Society for the Promotion of Agricultural Science, August, 1888, and published in Agricultural Science, vol. 2, No. 10, and Botanical Gazette, vol. 14, No. 3, p. 71.

The roots received by us were long and slender, and of various sizes; some of them were quite 2 feet long, and weighed several pounds. The bark, which contains the poisonous principle, if any be present, was carefully scraped off and has been preserved for subsequent examination. The analysis of the sample, calculated to dry substance, is given in the following table:

Serial No		5547
Ash	per cent	1.94
Oil (petroleum ether extract)	do	1.27
Ether extract (glucosides, alkaloids, organic acids, etc.)	do	.74
Alcohol extract (amids, sugars, resins, etc.)	do	17.43
Crude fiber	do	4.03
Starch	do	71.85
Albuminoids (calculated from nitrogen)	do	3.47
		100.73

In regard to the method of analysis, little need be said; it was carried on in accordance with the well-established rules of plant analysis as laid down by Dragendorff. The first extraction of petroleum ether gave the fat or oil alone, and the subsequent extraction with sulphuric ether gave the glucosides, alkaloids, and organic acids. That portion of nitrogen existing as amids has been estimated in the alcoholic extract. The total nitrogen was also estimated and entered as albuminoids; a small portion of the nitrogen has thus been counted twice in the total results which add up a little over 100. A characteristic feature of the cassava root is shown in the large amount of substance present soluble in alcohol. The amount of starch also compares fairly well with the best varieties of potatoes. On account of the large quantity of sugars present, the cassava root could be more economically used for the manufacture of glucose than for starch; their is no doubt, however, of the fact that a fine article of starch food can be made from the cassava root growing in this country.

In addition to the fresh root above noted, two samples of the dried root or cassava meal have also been examined. No. 5922 was sent to us, described as pulverized manihot root or cassava flour. The root is first peeled, chopped into thin sclices, dried in the sun two days, and pulverized. It was prepared by Prof. W. H. Kern, of Bartow, Fla. No. 5923 was labeled pulverized cassava, with the starch, or a portion of it, and glucose washed out, the remaining pulp dried in the sun, prepared by Professor Kern.

Professor Kern sent a letter with the samples, from which the following extracts are made:

Allow me to say that owing to the prodigious yield per acre of what we here know as cassava, and its alleged value as a feed and food plant, and for its yield of starch and glucose, it is attracting a very great deal of attention here now. The plant here grown is different from the manioc root of South and Central America: our root contains no poisonous elements which need to be dissipated by heat. It is customary here for many persons to make their own starch from it. The root, which must remain in the ground until one is ready to use it, is dug, washed, and its two inner and outer peelings removed; it is then grated and the pulp washed, the water poured off in a vessel and allowed to stand, when the pure starch settles in the bottom. The clear water is again drawn off and the starch allowed to dry. The pulp, after having the starch washed out, may be used at once in making puddings by the addition of milk, eggs, etc. This washed pulp may be sun-dried and thus kept, forming valuable meal or flour from which nice bread may be made. Necessitated as we are in south Florida to buy all our wheat flour, anything which acts as a substitute, either in whole or in part, is of great value to us.

The analyses of two samples of flour are given in the following table:

Serial No.	5922	5923
Water .... per cent..	10.56	11.86
Ash .... do....	1.86	1.13
Oil and fat .... do....	1.50	.86
Glucosides, alkaloids, and organic acids..do....	.64	.43
Amids, sugars, resins .... do....	13.69	4.50
Dextrine, gum, etc., by difference .... do....	2.85	5.63
Crude fiber .... do....	2.96	4.15
Nitrogenous bodies .... do....	1.31	1.31
Starch .... do....	64.63	70.13

From the above analyses it is seen that the cassava can never take the place of the flour made from cereals, as a food material, on account of the small portion of nitrogenous matter which it contains. It seems to me, however, that it might very well take the place of potatoes, and its value as a food should not be underestimated.

Mr. S. W. Carson, of Midland, Fla., has made some very valuable contributions to the literature of the native cassava. From a letter of his to the *Florida Farmer and Fruit Grower* of April 11, 1888, I make the following quotations:

As before stated, I regard the rolling pine lands, containing some willow oak, to be the best for cassava, and the southern counties to be best suited to it. Let the soil be well prepared by plowing and harrowing, rows checked about 4 feet apart, one piece laid in each hill. I think they should never be closer together than 4 feet, and 5 would be better. Cassava has been known to grow for three years in this country. It will continue to grow until the cold kills it, then by breaking off the stems when they are red, the stubble will sprout up in the spring. As to the seeds of the cassava they will ripen in about one year. If puddings, custards, etc., are desired, the roots must be peeled and grated; salt, sugar, etc., may be used according to taste. The Spaniards make bread of it simply by grating the root, and adding salt and a little soda. Now there is no doubt in my mind but that thirty tons of cassava root per acre can be produced. When I think of the tapioca, glucose, and starch there are in it, and how abundantly it can be turned into bacon and lard, milk and butter, mutton and beef, I feel confident that it will pay better than any other plant in the world.

Mr. J. H. Moore, of Keuka, Fla., in a letter to the same paper of November 24, 1887, describes some of the uses of cassava. From his letter I make the following extract:

Cut the stalks about 1 inch above the ground, just before frost; after cutting, the stalks should be left to dry in a cool place a few weeks, and then placed in a trench and covered until time for planting. Some save the stalks by keeping them in a dry, cool place until February and then plant. The roots should be dug as used; they will not keep in good condition out of the ground more than three or four days. It is perhaps the best feed we can raise for hogs; it is also a fine feed for poultry. We often bake it like sweet potatoes, and also slice and fry it like Irish potatoes.

M. Sacc has addressed a letter to the National Society of Agriculture of France, concerning the cassava which he calls "*Manihot utilissima.*" He is of the opinion that the poisonous varieties are different botanically from the innocent. Manihot is the bread of tropical regions. The innocent variety is cultivated in Bolivia, and the botanists there call it "manihot aïpi." The plant grows from 1 to 2 meters in height, with straight and naked stalks, since they only develop leaves at their extremities; the only care given to them in their cultivation is to keep them free from weeds. The roots, to the number of five to nine, are of the size of the closed hand. The following analysis of the roots of the manihot aïpi is given:

	Per cent.
Water	70.29
Starch	14.40
Sugar, salts, and malic acid	1.01
Fibrin and yellow coloring matter	.08
Crude fiber	3.16
Ash	10.82

From the above it is seen that the roots of the tropical plant are quite different from those produced in our own country. In regard to the distribution of the two varieties, M. Sacc makes the following observation:

In Cuba I have seen only the poisonous variety. The same is true of Brazil, where I have not seen the manihot aïpi except in the Swiss colony, Porto Real. As to the product of the two varieties, it is the same; the stalks, which are the size of the finger, are from 1 to 2 meters in height. I have not been able to analyze the leaves of this interesting vegetable, but as they are much sought after by cattle, they are probably very nutritious.

The above quotation from M. Sacc's paper I have taken from the *Revue Agricole* (ii, 6, pp. 81, 82), published at Port Louis Maurice.

The name cassava should be applied properly only to the purified starch derived from the roots of the plant. The plant is known under the botanical names *Janipha manihot*, *Manihot utilissima*, *Jatropha manihot*, *Manihot aïpi*, and *Jatropha Laefflingii;* it is also called the mandioc plant. The fleshy root of this plant yields the greatest portion of the daily food of the natives of tropical America, and its starch is known in this country under the name of tapioca. Manihot is a woody or shrubby plant growing from fleshy tuberous roots, the stems being smooth and the leaves generally long-stalked. The leaves of the poisonous variety usually have seven branches palmately divided; the leaves of the sweet variety are usually only five parted. In the "Treasury of Botany," page 718, the following remarks are made concerning these two varieties:

It is quite clear that while the root of one is bitter and a virulent poison, that of the other is sweet and wholesome, and is commonly eaten cooked as a vegetable. Both of them, especially the bitter, are most extensively cultivated over the greater part of tropical America, and yield an abundance of wholesome and nutritious food; the poison of the bitter kind being got rid of during the process of preparation it undergoes. The poisonous expressed juice, if allowed to settle, deposits a large quantity of starch known as Brazilian arrow-root or tapioca meal, from which the tapioca of the shops is prepared by simply torrefying the moist starch upon hot plates, the heat causing the starch grains to swell and burst and become agglutinated together. A sauce called *cassareep*, used for flavoring soups and other dishes, particularly the West Indian dish known as pepper-pot, is also prepared from this juice by concentrating and rendering it harmless by boiling. Another of the products of cassava is an intoxicating beverage called *piwarrie*, but the manner of preparing it is not calculated to render it tempting to Europeans. It is made by the women who chew cassava cakes and throw the masticated materials into a wooden bowl where it is allowed to ferment for some days, and then boiled. It is said to have an agreeable taste.

From the above analyses of cassava root, descriptions of its uses, and the amount of it that can be produced per acre, it is evident that it is destined to become a valuable agricultural product of the subtropical portions of our country.

LARD AND ITS ADULTERATIONS.

Lard is a term applied to the fat of the slaughtered hog separated from the other tissues of the animal by the aid of heat.

In the crude state it is composed chiefly of the glycerides of the fatty acids, oleic and stearic or palmitic, with small portions of the connective tissues, animal gelatine and other albuminous matters.

Kinds of lard.—According to the parts of the fat used and the methods of rendering it lard is divided into several classes. According to methods of rendering lard is classed as kettle and steam. From material used the following classification may be made:

Neutral lard.—Neutral lard is composed of the fats derived from the leaf of the slaughtered animal, taken in a perfectly fresh state. The leaf is either chilled in a cold atmosphere or treated with cold water to remove the animal heat. It is then reduced to a pulp in a grinder and passed at once to the rendering kettle. The fat is rendered at a temperature of 105° to 120° Fahr. (40° to 50° C.) Only a part of the lard is separated at this temperature and the rest is sent to other rendering tanks to be made into another kind of product. The lard obtained as above is washed in a melted state with water containing a trace of sodium carbonate, sodium chloride, or a dilute acid. The lard thus formed is almost neutral, containing not to exceed .25 per cent. free acid; but it may contain a considerable quantity of water and some salt. This neutral lard is used almost exclusively for making butterine (oleomargarine).

Leaf lard.—The residue unrendered in the above process is subjected to steam heat under pressure and the fat thus obtained is called leaf lard. Formerly this was the only kind of lard recognized in the Chicago Board of Trade and was then made out of the whole leaf.

Choice kettle-rendered lard; choice lard.—The quantity of lard required for butterine does not include all of the leaf produced. The remaining portions of the leaf, together with the fat cut from the backs, is rendered in steam jacketed open kettles and produces a choice variety of lard known as "kettle rendered." The hide is removed from the back fat before rendering and both leaf and back fat are passed through a pulping machine before they enter the kettle. Choice lard is thus defined by the regulations of the Chicago Board of Trade:

"*Choice lard.*—Choice lard to be made from leaf and trimmings only, either steam or kettle rendered, the manner of rendering to be branded on each tierce."

Prime steam lard.—The prime steam lard of commerce is made as follows: The whole head of the hog, after the removal of the jowl, is used for rendering. The heads are placed in the bottom of the rendering tank. The fat is pulled off of the small intestines and also placed in the tank. Any fat that may be attached to the heart of the animal is also used. In houses where kettle-rendered lard is not made the back fat and trimmings are also used. When there is no demand for leaf lard the leaf also is put into the rendering tank with the other portions of the body mentioned. It is thus seen that prime steam lard may be taken to represent the fat of the whole animal, or only portions thereof. The quantity of fat afforded by each animal varies with the market to which the meat is to be sent. A hog trimmed for the domestic market will give an average of about 40 pounds, while from one destined for the English market only about 20 pounds of lard

will be made. Prime steam lard is thus defined by the Chicago Board of Trade:

"*Prime steam lard.*—Standard prime steam lard shall be solely the product of the trimmings and other fat parts of hogs, rendered in tanks by the direct application of steam, and without subsequent change in grain or character by the use of agitators or other machinery, except as such change may unavoidably come from transportation. It shall have proper color, flavor, and soundness for keeping, and no material which has been salted shall be included. The name and location of the renderer and the grade of the lard shall be plainly branded on each package at the time of packing."

This lard is passed solely on inspection, the inspector having no authority to supervise rendering establishments in order to secure a proper control of the kettles. It is reported on authority that the large intestines, after proper cleaning, are placed in the rendering tanks. According to the printed regulations any part of the hog containing fat could be legally used.

Since much uncertainty exists in regard to the disposition which is made of the guts of the hog I have had the subject carefully investigated. Following are the results of the study:

Guts.—Definition of the term as used by hog-packers is: Everything inside of a hog except the lungs and heart, or, in other words, the abdominal viscera complete. The material is handled as follows:

When the hog is split open the viscera are separated by cutting out the portion of flesh surrounding the anus and taking a strip containing the external urino-generative organs. The whole viscera are thrown on a table and divided as follows: The heart is thrown to one side and the fatty portion trimmed off for lard. The rest goes into the offal tank or sausage. The lungs and liver go into the offal tank or sausage. The rectum and large intestines are pulled from the intestinal fat and peritoneum and along with the adhering flesh and genito-urinary organs sent to the trimmer. All flesh and the above-mentioned organs are trimmed off and the intestine proper is used for sausage casing. The trimmings, including the genito-urinary organs, are washed and dumped into the lard tank. The small intestine is also pulled from the fatty membrane surrounding it and saved for sausage casings. The remaining material, consisting of the peritoneum, diaphragm, stomach, and adhering membranes, together with the intestinal fat, constitute the "guts," which are seen undergoing the process of washing, which is usually conducted in three or four different tanks. As the "guts" pass into the first tank the stomach and peritoneum are split open, and also any portions of the intestines which sometimes adhere to the peritoneum. After receiving a rough wash they are passed from tank to tank when, after the third or fourth wash, they are ready for the rendering tank. The omentum fat is cut from the kidneys and the kidneys, with a little adhering fat, go into the rendering tank. Spleen and pancreas go into lard tanks, as do also the trachea, vocal cords, and œsophagus.

To sum up, it is safe to say that everything goes into lard, or rather the lard tank, with the following exceptions:

(1) The intestines proper, which are saved for sausage casings.
(2) The liver and lungs.
(3) That part of the heart free from fat.

I have been told that in killing small hogs, and also when there is

small demand for sausage casings, it is frequently the practice to split the intestines so as to save expense of pulling from the fat; and after washing, fat and all go into the tank. I have no other evidence except that I have often seen lard with a distinctly "gutty flavor," which must have been caused by this or some similar mode of handling. Of course it will often happen that the intestines break off and portions adhere to the enveloping tissue, and consequently get into the tank after washing.

It is a commercial fact that sausage casings are worth more than the small amount of adhering fat, and consequently packers will save them. Small hogs produce small casings difficult to pull, and it is reasonable to believe that they will be handled in the simpler manner. They break so easily they are hardly worth saving separately. It is stated by lard manufacturers that the lard made from the parts of the intestines mentioned above is used for the manufacture of lard oil and soap, and does not enter into the lard of commerce.

Butchers' lard.—The small quantities of lard made by butchers is usually "kettle rendered," after the manner practiced by small farmers in making lard for home consumption. Often the scraps are saved up for a considerable length of time by the butchers before rendering, and this is likely to increase the free acid present. This lard is also frequently dark colored and contains a considerable quantity of glue. In New York this lard is known as "New York City lard."

Other hog-fat products.—There are many other hog-fat products not used in the manufacture of lard or compound lard a description of which, however, may prove useful here.

White grease.—This grease is made chiefly from hogs which die in transit by being smothered or frozen. Formerly it was also made from animals dead of disease, but this product has of late been diminished on account of certain State laws requiring the carcasses of hogs which have died of cholera to be buried. This grease is made from the whole animal with the exception of the intestines. The latter are rendered separately and make "brown grease." The rendering is done in closed tanks at a high pressure. The residue is used in the manufacture of fertilizer. White and brown grease are used chiefly in the manufacture of low-grade lard oils and soap.

Yellow grease.—Yellow grease is made by packers. All the refuse materials of the packing-houses go into the yellow-grease tank, together with any hogs which may die on the packers' hands. Yellow grease is intermediate in value between white and brown. It is used for the same purposes.

Pigs'-foot grease.—This grease is obtained chiefly from the glue factories, and is used for making lard oils and soap.

Stearines.—The stearines are the more solid portions of the animal fats remaining after the more fluid portions have been removed by pressure. The stearines used in the manufacture of compound lard are lard stearine, derived from lard, and oleo-stearine derived from a certain quality of beef tallow.

Lard stearine.—The lard stearine used in compound lard is made as follows:

The prime steam lard, if properly crystallized and of the right temperature (from 45° to 55° Fahr., winter, 55° to 65° summer) is sent at once to the presses. If not properly grained, it is remelted and kept in a crystallizing room at 50° to 60° Fahr. until the proper grain is

formed. The lard is then wrapped in cakes with cloth, each cake containing 10 to 20 pounds. The cakes are placed in a large press, with suitable septa to facilitate the egress of the oil. These presses are sometimes 40 to 50 feet in length, and when first filled 12 to 18 feet high. The pressure is applied very gradually at first by means of a lever working a capstan about which the chain is wrapped attached to the upper movable part of the press.

The oil expressed, prime or extra lard oil, is used for illuminating and lubricating purposes. The resulting stearine is used for making compound lard and is worth more than the lard oil. It has about .5 per cent. free fatty acid (less than the lard oil) and crystallizes in long needles, making the texture tough.

Oleo stearine.—This product is made chiefly from the caul fat of beeves. This fat is rendered in open kettles at a low temperature. The resulting tallow is placed in cars in a granulating room where it is allowed to remain for thirty-six to forty-eight hours at a temperature 80° to 90° Fahr. The contents of the cars are then mixed and placed on a revolving table where they are made into a cake. This cake is then wrapped with strong cotton cloth and placed in a strong press where a gradual pressure at 90° Fahr., becoming very strong at the end, is applied for one to two hours. The expressed oil, known as oleo oil, is used in the manufacture of butterine. The stearine is removed from the press as white, hard cakes and is used for adulterating lard. The oil is sometimes filtered with a small percentage of fuller's earth to improve its color and brightness.

Mutton tallow.—A fine article of mutton tallow is also sometimes used in lard, but the objection to the flavor is sufficient to limit its use to a small amount.

The following general remarks on beef fat will be found instructive:

Beef fat.—Before the day of the oleomargarine industry, all fat rendered from the tissues of cattle was known commercially as tallow. Since then differentiation has taken place, and the term tallow no longer is sufficient to designate the several products obtained from the rendered fat of the beef. We have first "butter stock," which is rendered from the caul fat at a low temperature, and from which is manufactured by means of pressure—

(1) Oleo oil.

(2) Oleo stearine (beef stearine).

The kidney fat, as a rule, is left with the carcass and constitutes what is known as suet. Marrow stock, as its name implies, is rendered marrow fat, and when properly prepared is almost equal to butter stock in quality. Tallow is made from the trimmings and portions of the viscera. Its color varies from white to yellow, according to the portions of the animal which have been used and the care with which they have been prepared for rendering, and the temperature at which rendered. When freshly and carefully rendered tallow should show less than 1.5 per cent. of free fatty acid. The tallow on the market will show anywhere from 2 to 10 per cent. Its flavor varies, never being good enough for lard.

PROPERTIES OF PURE LARD.

PHYSICAL PROPERTIES.

Specific gravity.—The specific gravity of a pure lard varies rapidly with the temperature. It is not convenient to take the specific gravity of a lard at a lower temperature than 35° or 40°, inasmuch as

below that temperature solidification is apt to begin. The specific gravity, therefore, is usually taken at 35° or 40° or at the temperature of boiling water, viz, 100°. At 40° the specific gravity of a lard varies from .900 to .904. At 100° the specific gravity is found to vary between the numbers .860 and .865. The specific gravity of pure lard is very near that of many of the substances used in adulterating it, but is distinctly lower than that of cotton oil, and is of very great distinctive value in analysis.

Melting point.—The melting point of a pure lard is a physical characteristic of great value. The melting point of the fat of the swine varies with the part of the body from which it is taken. The fat from the foot of the swine appears to have the lowest melting point, viz, 35.1°. The intestinal fat seems to have the highest, viz, 44°. In fat derived from the head of the animal the melting point is found to be 35.5°, while the kidney fat of the same animal shows a melting point of 42.5°. In steam lards, representing the lards passed by the Chicago Board of Trade, the melting point, for ten samples, was found to vary between 29.8° and 43.9°. In general it may be said that the melting point of steam lards is about 37°. In pure lards derived from other localities the melting point was also found to vary. A sample of lard from Deerfoot Farm, Southborough, Mass., was found to have a melting point of 44.9°, while a pure lard from Sperry & Barnes, New Haven, Conn., melted at 39°. While the melting point can not be taken as a certain indication of the purity of a lard, nevertheless a wide variation from 40° in the melting point of a lard should lead at least to a suspicion of its genuineness, or that it was made from a special part of the animal. Perhaps one reason why the melting point has not been more highly regarded by analysts is because of the unsatisfactory method of determining it; but when it is ascertained by the method used in these investigations it becomes a characteristic of great value.

Color reaction.—The coloration produced on pure lard by certain reagents serves as a valuable diagnostic sign in the analysis of lard and its adulterations. Various reagents have been employed for the production of characteristic colors in fats, but of these only two are of essential importance. They are sulphuric and nitric acids. Pure lard, when mixed with sulphuric and nitric acids of the proper density, as indicated hereafter, gives only a slight color which varies from light pink to faint brown. The variation produced in the color by pure lards is doubtless due to the presence in various quantities of certain tissues of the animal other than fat. For instance, a variation in the amount of gelatinous substance mechanically entangled with the lard or of the tissues composing the cells in which the lard was originally contained would be entirely sufficient to account for the slight difference in color produced by lards of known purity. It might, therefore, be difficult to distinguish accurately between a pure lard containing a considerable amount of other tissues from the animal and one which contained a small amount of adulteration. The coloration produced, therefore, by the acids named should not be relied upon wholly in distinguishing pure from adulterated lards; but the character of such coloration should be carefully noted in the analyst's book. In the steam lards examined some of the remarks describing the coloration produced are as follows:

"Trace of color," "faint pink," "bright pink," "light red," "yellowish," etc. For pure lards of micellaneous origin some of the de-

scriptions are as follows: "Brownish pink," "trace of yellow," "marked red brown," "no color," "slight coloration," etc.

Refractive index.—The deviation produced in the direction of a ray of light in passing through a film of melted fat is also a valuable physical characteristic. This deviation is usually measured as the quotient of the sine of the angle of incidence by the sine of the angle of refraction and is known as the refractive index. The refractive index of pure water, at 25° on the instrument used in these investigations, was 1.3300. The refractive index of the samples of lard was made at as low a temperature as possible to preserve fluidity, viz, between 30° and 36°. The rate of variation in the refractive index for each degree of temperature, experimentally determined, for lard oil was .000288. This number may also be taken to represent the variation for lard. The refractive index varies inversely as the temperature. The mean number for pure lard at 25° is about 1.4620. The refractive index of pure lard is distinctly less than that of cotton oil at the same temperature, and is therefore a valuable characteristic for analytical purposes.

Rise of temperature with H_2SO_4.—More valuable for diagnostic purposes than the physical property already considered is the rise of temperature which lard undergoes when mixed, under proper conditions, with sulphuric acid. There is such a marked difference between the numbers representing the rise of temperature in pure lard and those of the adulterations usually employed in the manufacture of mixed lard as to give this number a high analytical value. With steam lards, ten samples, the extremes, as registered by the thermometer, were 38.8° and 42.1°. For pure lards of miscellaneous origin, one from Deerfoot Farm, Southborough, Mass., gave a rise of temperature of 37.1°, and a pure leaf lard from Sperry & Barnes, New Haven, Conn., a rise of temperature of 46.2°.

The value of this characteristic is so great as to lead me to expect approximately reliable quantitative results from a general determination of the actual amount of heat produced in an appropriate calorimeter. I am at present attempting to devise an instrument by which the actual number of colories produced by mixing definite quantities of fats and oils and sulphuric acid can be accurately determined.

Crystallization point of fatty acids.—The method described in the work of Dalican for determining the crystallizing points of fatty acids gives valuable data concerning the nature of pure lard and also of the relative amount of stearic and oleic acids present in the mixture. In pure lards the crystallizing point was found to vary, in the ten samples of steam lard already mentioned, from 35.4° to 39.5°. In pure lards the variation was found to be from 32.1° to 42.7°.

Melting point of fatty acids.—In connection with the crystallizing point of the fatty acids, the temperature at which a thin disk of the same becomes a perfect sphere, otherwise known as the melting point, is also of value. This temperature has been determined in the fat acids derived from steam and pure lards. In the steam lards these numbers vary from 41.4° to 43°. In pure lards the variation was from 36.9° to 46.6°.

CHEMICAL PROPERTIES.

Volatile acids.—The quantity of volatile acid, as ordinarily estimated in pure lard, is extremely minute. Unless some suspicion of

adulteration is awakened the search for such volatile or soluble acid may be omitted. Measured in a quantity of deci-normal alkali solution for 5 grams of the fat the mean quantity of volatile acid in a pure lard may vary from .2 to .4 of a cubic centimeter. The determination, therefore, of the volatile acid in the examinations of lards has none of that high diagnostic value which attaches to it for the examination of butters.

Saponification equivalent.—The amount of caustic alkali necessary to saponify the fatty acids of the common glycerides is known as its saponification equivalent or number. The operation is usually known as Koettstoffer's process. The number of parts of a glyceride saponified by one molecule of alkali is represented by one-third of the molecular weight of the glyceride in question. The saponification equivalent, therefore, represents the number of grams of an oil or fat saponified by one equivalent in grams of an alkali. The percentage of caustic potash used for saponifying a lard is about 20 and the mean saponification equivalent about 285.

In the steam lards examined by us, leaving out one result of doubtful accuracy, the extreme variations were 276.14 and 290.05, and the mean 283.45. In pure lards the extremes were 272.64 and 294.14, and the mean 280.33.

Iodine number.—The quantity of iodine absorbed by an oil or fat affords one of the most valuable indications of its constitution. The glycerides of the oleine series have the property of absorbing the halogens. On the other hand the glycerides of the palmitic or stearic series do not absorb iodine. Hence in a fat or oil from which the presence of linoleine and its analogous body can be excluded the quantity of iodine absorbed may become a fairly accurate measure of the amount of oleic acid present. The lard derived from different portions of the swine varies largely in the amount of oleine contained therein. For instance, a sample of intestinal lard absorbed 57.34 per cent. of iodine; the leaf lard from the same animal absorbed 52.55 per cent.; the foot lard, 77.28 per cent.; the head lard, 85.03 per cent. In the steam lards mentioned the variation in the percentage of iodine absorbed was from 60.34 to 66.47 per cent., and the mean 62.86 per cent. In pure lards the mean was 62.45 per cent. Thus in lards of known purity the amount of iodine absorbed will indicate the probable part of the animal from which the fat in the lard was derived. The wide variation between the iodine numbers of pure lard and those of the adulterants used in making refined lard serves to render this number of the greatest importance in analytical work.

The reaction with nitrate of silver.—Pure lards treated with a solution of nitrate of silver after the method of Bechi, or the fatty acids thereof after the method of Milliau, give no reduction of metallic silver, or at most only a trace or slight coloration. This fact is of the utmost importance in the analysis of lard.

Microscopical appearances.—Lard examined with the microscope shows a definite crystalline structure but does not plainly reveal the character of the crystals. When lard is slowly crystallized from a mixture of ether, beautiful rhombic crystals of stearine are obtained which are easily distinguished from the groups of fan-shaped crystals given by beef or mutton fat under similar conditions.

Moisture in lard.—The quantity of water in pure lard varies from a mere trace to .2 per cent.

PROPERTIES OF LARD ADULTERANTS.

COTTONSEED OIL—PHYSICAL PROPERTIES.

Specific gravity.—Cottonseed oil being liquid at ordinary temperatures its specific gravity can be easily taken at the temperature of the room. For purposes of comparison the rate of variation in the specific gravity of the oil can be determined, and its specific gravity at any given temperature calculated; or its specific gravity can be directly determined at 35°, 40°, or 100°, as may be desired. In the samples examined the specific gravities of the oils at 35° vary from .9132 to .9154. The mean for nineteen samples is .9142. These numbers show the relative weight of the oil and equal volumes of water at the same temperature, the weight of water being taken as unity.

Melting point.—Since cotton oil solidifies only at a temperature near or below the freezing point of water its melting point has not been determined.

Color reaction.—The color produced in cotton oil by sulphuric and nitric acids is a characteristic mark of the greatest value. This color varies from deep reddish brown to an almost black color. Some of the descriptions of the color produced in cotton oil, taken from the note-book, are as follows: "Dark brown," "very brown black," "deep red brown," "very red," "yellow brown," etc. It must not be forgotten, however, that these colors can be produced by other oils, and hence their occurrence is not conclusive of the presence of cotton oil.

Refractive index.—The refractive index of cotton oil is distinctly higher than that of lard. The variation in the index of refraction is inversely as the temperature. The mean rate of variation for each degree is .000288. For a temperature of 25° the mean refractive index of the samples examined was 1.4674. The rate of variation in the index of refraction in cotton oil is sensibly the same as that for lard.

Rise of temperature with sulphuric acid.—The rise of temperature which cotton oil suffers when mixed with sulphuric acid is a very prominent diagnostic sign. In the samples examined, the lowest increment of temperature noted was 80.4° and the highest 90.2°. The mean rise of temperature was 85.4°. Cotton oil therefore gives more than double the increment of temperature shown by pure lard under the same conditions.

Crystallization point of fatty acids.—Since cotton oil is fluid even at low temperatures (viz, 0°), the determination of its melting point is only a matter of scientific interest. The point at which its free acids crystallize is, however, easily determined, according to the method of Dalican.

The mean crystallizing point of the acids examined was 33.6°, the minimum was 30.5°, the maximum was 35.2°.

Melting point of fatty acids.—The melting point of the free acids of cotton oil was determined both in capillary tubes and by observing the deportment of the acid on the bulb of a delicate thermometer protected by a glass flask. The two sets of data were almost identical.

The mean melting point of the acids examined was 39.3°, the maximum was 44.4°, the minimum was 34.6°.

CHEMICAL PROPERTIES.

Volatile acids.—The statements made in regard to the volatile acids in a pure lard are also applicable to cottonseed oil. For 5 per

cent. of cotton oil the quantity of $\frac{N}{10}$ alkali consumed is slightly greater than for pure lard and may amount to as much as .5 c. c. If cocoa oil is present the number will be much higher. Five per cent. of pure cocoa oil will consume from 7 to 8 cc of the deci-normal alkali.

Saponification equivalent.—In the samples examined, the mean saponification equivalent was 283.8, although in some instances quite a difference was noticed from this figure.

Iodine number.—Cotton oil possesses in a much higher degree than lard the property of absorbing iodine. This is due not only to the large percentage of oleic acid which it contains, but also probably to the presence of a small amount of linoleic acid or some homologue thereof. In the samples examined, in no case did the iodine number fall below 100 and in one instance it rose to 116.97. The mean iodine was 109.2.

Reaction with nitrate of silver.—A more important property even than its power of absorbing iodine is shown by cotton oil in the reduction of silver to the metallic state under certain conditions.

The test may be applied, as already indicated, either to the oil itself or to the fatty acids thereof. The silver is either reduced in the form of a metallic mirror deposited on the sides of the vessel or in minute black particles which give a brown or black appearance to the liquid. In some cases the liquid shows a greenish tint.

Other properties.—The refined cotton oil used in adulterating lard has a pleasant taste, is almost odorless, and possesses a faint yellow color. Its resemblance to olive oil is so marked that for all culinary purposes it forms an excellent substitute therefor. Cotton oil possesses slight drying qualities, which render it unfit for lubricating machinery. It can never take, therefore, the place of sweet oil for that purpose.

PREPARATION OF COTTON OIL.

The cotton seed from various sources is put through a screen to take out the bolls and coarse material. The seed is then put through a gin to remove as much as possible any remaining lint, of which about 20 pounds per ton of seed are obtained.

The clean seed is next sent to a huller composed of revolving cylinders covered with knives which cut up both seed and hull. The chips are then conveyed to the screen placed on a vibrating frame, through which the kernels fall. The hulls are carried by an endless belt to the furnaces where they are burned. The kernels of the seed are conveyed to crusher rolls, where they are ground to a fine meal. The meal is then sent to a heater where it remains from twenty to forty minutes. These heaters have a temperature of 210° to 215°. The hot meal is formed into cakes by machinery. These are wrapped in cloth and placed in the press. About 16 pounds of meal are put in each cake. The cakes are placed in a hydraulic press, where a pressure of from 3,000 to 4,000 pounds per square inch is applied. The press is also kept warm. The expressed cake contains only about 10 per cent. of oil. The cake is sold as cattle food or for fertilizing purposes. The crude oil as thus expressed contains 1.5 per cent. of free acid. The chief cotton-seed presses of the country are located at the following points:

COTTONSEED OIL MILLING POINTS.

Arkansas—Little Rock, Argenta, Fort Smith, Texarkana, Brinkley, and Helena.

Alabama—Selma, Mobile, Montgomery, Eufaula, and Huntsville.
Georgia—Atlanta, Augusta, Albany, Columbus, Macon, and Rome.
Tennessee—Memphis, Jackson, Nashville, and Dyersburgh.
Texas—Brenham, Dallas, Galveston, Houston, Palestine, and Waco.
Illinois—Cairo.
Louisiana—New Orleans, Shreveport, Baton Rouge, and Monroe.
Missouri—Saint Louis.
Mississippi—Clarksdale, Columbus, Canton, Grenada, Greenville, Meridian, Natchez, Vicksburg, and West Point.
North Carolina—Charlotte and Raleigh.
South Carolina—Columbia and Greenville.

The oil is chiefly pressed in winter, since it is difficult to keep it for summer work; some mills are, however, operated during the summer. The crude oil is shipped in tanks holding from 36,000 to 45,000 pounds each. When the oil is shipped north in winter it usually becomes solidified. In order to get it out of the tanks they are placed on switches and a jet of steam is introduced into the tank and the oil gradually melted out. Another method consists in covering the tank with wood, forming a chamber, into which exhausted steam is introduced. Gutters are provided along the railroad tracks into which the oil flows, and is conducted into the receiving tanks. From the receiving tanks it is pumped into large receivers called scale tanks, where the crude oil is weighed.

Refining process.—After weighing the oil is pumped into refining kettles. These are of various sizes, the largest ones being 20 to 25 feet deep and 15 feet in diameter. These tanks are furnished with steam coils for the purpose of heating the oil and with appropriate machinery for keeping it in motion. A solution of caustic soda is used for refining. This solution is made from 10° to 28° Baumé in strength and various quantities are used according to the nature of the oil operated upon. After the addition of the caustic soda the mixture is agitated for forty-five minutes and kept at a temperature of 100° to 110°F. The contents of the tank are then allowed to stand six to thirty-six hours when the solid matters, soap, and substances precipitated by the caustic akali gather at the bottom. This mixture is called foots and is used for making soap. The yellow oil resulting by this process is purified by being heated and allowed to settle again or by filtration and is called summer yellow oil. Winter yellow oil is made from the above material by chilling it until it partially crystallizes and separating the stearine formed, about 25 per cent., in presses similar to those used for lard. This cotton-oil stearine is used for making butterine or soap.

White oil.—The yellow oil obtained as above is treated with from 2 to 3 per cent. of fuller's earth in a tank furnished with apparatus for keeping the mixture in motion. When the fuller's earth has been thus thoroughly mixed with the oil the whole is sent to the filter press. The fuller's earth has the property of absorbing or holding back the yellow coloring matter so that the oil which issues from the press is almost white. This white oil is the one which is chiefly used for making compound lard.

Stearines.—The stearines used in the adulteration of lard are derived chiefly from lard, tallow (suet), and cotton oil. These are generally called oleo stearine, lard stearine, and cotton-oil stearine, respectively.

PHYSICAL PROPERTIES.

Specific gravity.—The specific gravity of stearines may be taken in their solid state or in a liquid state at a high temperature, best at 100°. The numbers are slightly lower than those for lard.

Melting point.—The melting points of the stearines are higher than the natural glycerides from which they are derived. A prime oleo stearine from Armour & Co., Chicago, showed a melting point of 51.9°. A prime lard stearine from the same firm showed a melting point of 44.3°, which is only slightly higher than the mean melting point of pure lards. The lowest melting point of any stearine examined was a sample of dead-hog stearine from J. P. Squire, Boston, which was 38.2°. The highest observed melting point in the stearines examined was an oleo stearine from N. K. Fairbank & Co., Chicago, showing 53.8°. The high melting point of the stearines is a characteristic of great value in the adulteration of lard, since it serves to counteract the influence of the cotton oil, which of course tends to lower the melting point of any lard mixture into which it may enter. The influence of the various constituents, however, on the melting point does not seem to be proportional to the respective quantity of each therein. For instance, a mixture of 25 per cent. of cotton oil having a melting point about zero, with 25 per cent. of an oleo stearine having a melting point of only about 12° above the normal for pure lard, with 50 per cent. of pure lard of normal melting point, might not show a lowering of the melting point at all proportional to the presumable influence of the cottonseed oil present. The cotton-oil stearine, as might be expected, has a melting point very much below that of the similar products derived from lard and tallow.

Color reaction.—The color reactions produced in the stearines by sulphuric and nitric acids are much the same as those produced in the original glycerides from which they were derived. Cotton-oil stearine shows a less intense color perhaps than the original oil; while in the case of tallow and lard stearines the coloration is not marked enough to be susceptible of description.

Refractive index.—The refractive index of the stearines is sensibly lower than that of the original glycerides. The refractive index of a prime lard stearine from Fairbank & Co. was found to be 1.4555 at 29.9°; of a white cotton-oil stearine from a Southern cottonseed oil company the refractive index was 1.4645 at 29.8°.

Rise of temperature with sulphuric acid.—With the lard and tallow stearines no degree of comparison can be made in the rise of temperature with that produced in the original glycerides, on account of the high initial temperature which is necessary for the conduct of the experiment. Allowing for the difference in initial temperature, however, the stearines deport themselves very much as the glycerides from which they are derived.

CHEMICAL PROPERTIES.

Volatile acids.—The amount of volatile acids in the stearines mentioned is so small as to be negligible.

Saponification equivalent.—The numbers are essentially the same as those of the original glycerides.

Iodine number.—The percentage of iodine absorbed by the stearines is, as is to be expected from the fact that they contain less triolein, markedly less than that of the original glycerides. The fact

that the stearines possess that property in this diminished degree is of quite as much importance from an analytical point of view as their high melting point. Thus the mixture of a stearine with a low iodine number with cotton oil of a high iodine number shows a percentage of iodine absorption not markedly different from that of pure lard. One prime oleo stearine examined showed an iodine absorption of only 17.38 per cent. Another oleo stearine showed 26.81 per cent. The lard stearines showed higher numbers, viz, in two cases 44.24 per cent. and 49.78 per cent. The cotton-oil stearines showed iodine numbers varying from 85.28 per cent. to 99.39 per cent.

Reaction with nitrate of silver.—The stearines react with nitrate of silver in a manner entirely comparable with that of their original glycerides.

Microscopical appearances.—Stearine derived from beef or mutton tallow shows under the microscope the characteristic fan-shaped crystals already noticed. Lard stearine on the other hand gives crystalline groups similar to those already mentioned in the case of lard.

Moisture.—Properly prepared stearine contains only a trace of moisture.

Other adulterants of lard.—It has been claimed that other substances than those mentioned have been used in the adulteration of lard, but these claims seem to rest on no valid foundation. Among these substances dead-hog grease or dead-hog stearine is the one most frequently mentioned. The term dead-hog grease is used to indicate the oil or lard obtained from animals which die of disease or are smothered in transportation or die on the way to the slaughtering houses. The fat of animals very recently dead, unless death takes place from disease, and taken before any decomposition sets in has chemically the same characteristics as that derived from animals slaughtered. If, however, the animals have been dead some time before rendering a considerable decomposition of the glycerides takes place and the amount of free acid in the fat is thus largely increased. Such fat also shows a distinctly unpleasant odor by which it can readily be distinguished from genuine lard. Peanut oil and some other vegetable oils have also been mentioned as adulterants of lard. While it may be true that many attempts have been made to use the above substances in the adulteration of lard on a small scale, it is also quite true that such attempts have never attained any importance from a commercial point of view.

Mixing.—The term "refined lard" has long been used to designate a lard composed largely of cotton oil and stearine. The largest manufacturers of this kind of lard have now abandoned this term and are using the label "lard compound" instead. This is but just to the consumers of this article who are likely to be misled by the term "refined lard." The prime steam lard in a state of fusion, the stearine, also in a liquid condition, and the cotton oil are measured in the proportions to be used and placed in a tank at a temperature of 120° to 160° Fahr. In this tank the ingredients are thoroughly mixed by means of paddles operated by machinery. After mixing the compound lard passes at once to artificial coolers where it is chilled as soon as possible; it is thence directly run into small tin cans or large packages and prepared for market.

PROPERTIES OF ADULTERATED LARDS.

In external appearance to an unskilled person adulterated lards are not appreciably different from the pure article. An expert, however,

is generally able to tell by taste, odor, and grain a mixed lard from a pure one. There is usually enough lard in the adulterated article to give to it the taste and odor of a genuine one. Mixtures of fat, however, have been made, and perhaps sold as lard, which contained no hog grease whatever. In the following descriptions an endeavor has been made to give the chief characteristics of an adulterated lard on the same plan as the descriptions of pure lard and the adulterants thereof which precede.

PHYSICAL PROPERTIES.

Specific gravity.—But little stress can be laid upon the numbers representing the specific gravity of adulterated lards, since the materials of which they are composed have nearly the same specific gravity as the pure article. The addition of cotton oil, however, raises the specific gravity, and when this substance is present in quantities above 15 per cent. its influence on the specific gravity of the sample is marked. At 35° the specific gravity of adulterated lards varies from .906 to .910.

Melting point.—The melting point of the adulterated lards is in some cases slightly lower than that of pure lards. This arises from the fact, which has already been noticed, of the low melting point of the cotton oil, which is one of the principal adulterants used. The numbers representing the melting points of adulterated lards, emphasize the fact, which has already been noted, that the lowering of the melting point is not theoretically proportional to the contents of cottonseed oil found in the adulterated lards of commerce. In a number of samples of lards containing cottonseed oil from Fairbank & Co. the lowest melting point was 31.3° and the highest 41.9°. In the series of samples from Armour & Co. the lowest melting point noticed was 38.9° and the highest 43°3°. The melting point of the Armour samples approaches much nearer that of pure lard than those received from Fairbank & Co. Although the melting point is not of itself a property of very great importance from an analytical point of view, yet its determination should never be neglected in a comprehensive analytical examination.

Color reaction.—The amount of coloration shown by an adulterated lard, when treated with sulphuric or nitric acid, depends upon the percentage of cotton oil which it contains, since from a commercial point of view the introduction of a small amount of cotton oil would not prove profitable. We find in the adulterated lards of commerce, as a general rule, strong color reactions. It might be possible, however, to mix with a pure lard so small a quantity of cotton oil as to render doubtful to the analyst the character of the color reaction produced. Some of the colors produced in the adulterated lards examined, as copied from the note-books, are as follows: "Light brown," "pink red brown," "light yellow red," "light pink," "deep brown," "red," "deep red brown," etc. The appearance of a pinkish tint is often found in adulterated lards containing a notable portion of beef-fat stearine, although this coloration is not considered a certain indication of the presence of this substance.

Refractive index.—The refractive index of the mixed lards naturally varies with the proportion of cottonseed oil which may be present. The greater the quantity of cottonseed oil the higher the refractive index. The refractive index of the Armour mixed lards is decidedly lower than that of the Fairbank samples. The following is the number representing the mean refractive index of the Ar-

mour samples at 25°, viz. 1.4634. The number representing the mean refractive index of the Fairbank samples is 1.4651. The refractive index is a much more important property in the sorting of lards than the melting point, or perhaps even than the specific gravity.

Rise of temperature with sulphuric acid.—As is to be expected we find here also the greatest variations depending on the nature and the quantity of the adulterants present. The presence of tallow stearine tends to diminish the rise of temperature with sulphuric acid, while cottonseed oil has the opposite effect. As the relative proportion of these two ingredients and also the amount of pure lard varies we may expect corresponding variation in the temperature shown on mixing the lard with sulphuric acid. In the samples of Armour's lards examined the highest rise of temperature noticed was 58.9° and the lowest 42.1°. This latter number is almost identical with that furnished with pure lards. In Fairbank's lards the least rise of temperature noticed was 51.3° and the greatest 68.8°. These numbers show a larger proportion of cotton oil in the Fairbank than in the Armour samples. This rise of temperature as a diagnostic sign is valuable and its determination should never be omitted.

CHEMICAL PROPERTIES.

Volatile acids.—The remark which has been made in regard to the volatile acids of pure lards and their adulterants is also applicable for mixed lards. The amount is so minute as to be of no value from an analytical point of view.

Saponification equivalent.—The numbers representing the saponification equivalent do not afford any particular indication of the kind of adulteration used. In the samples of Fairbank mixed lards examined, the mean saponification equivalent found was 279.4. In the Armour samples it was 275.

Iodine number.—The amount of iodine absorbed by a mixed lard gives a valuable indication of the kind of the ingredients which have been added to it. It has already been seen that the stearines, especially those derived from tallow, have a very low iodine number, while cottonseed oil has a very high one. It is therefore possible to mix these two substances together so that the resulting iodine number may be about the same as that of pure lard, viz. 60 per cent. In the samples of the Armour mixed lards examined the mixture seems to have been made in about the proportion indicated. The lowest iodine number observed in these lards was 54.11 per cent., which is decidedly less than that of normal pure lard. The highest number observed was 71.19 per cent. The other numbers were slightly above those obtained for pure lard. In the samples of mixed lards from Fairbank & Co. the iodine numbers are much higher. The lowest number observed was 78.24 and the highest 94.78 per cent.

Reaction with nitrate of silver.—Mixed lards containing cotton oil show a reduction of metallic silver in a greater or less degree according to the proportion of cotton oil present. In every case where cotton oil was known to be present in a mixed lard this reaction was noticed. It would be possible, however, to put so small a portion of cotton oil into a lard as to render difficult the positive detection of it by the nitrate of silver test.

Microscopic appearances.—The mixed lards show in the field of vision of the microscope distinct tufted crystals of the stearines which have been used as adulterants. The rhombic crystals of pure

lard are also often noticed in this field. The microscope is a most valuable aid in detecting lard adulterations.

Moisture in mixed lards.—Mixed lards generally contain only a trace of water. In one instance, however, water appears to have been added as an adulterant, over 30 per cent. of it having been found. The use of water as an adulterant of lard, however, is not common.

COMPARISON OF PROPERTIES OF LARDS AND COMPOUND LARDS.

The mean results of the analytical data are as follows:

Kind of samples.	Specific gravity.	Saponification equivalent.	Melting point of the glycerides.	Melting point of the fat acids.	Crystallizing point of fat acids.	Rise of temperature with sulphuric acid.	Percentage of iodine absorbed.	Refactive index.
			C°	C°	C°	C°		
Pure lard	.9053	280.3	40.7°	43.3°	39.6°	41.5°	62.48	1.4620
Lard of miscellaneous origin	.9067	274.4	41.7°	42.9°	39.6°	45.7°	64.34	1.4633
Prime steam lard	.9055	283.5	37.0°	42.1°	38.6°	39.9°	62.86	1.4623
Armour's lards	.9060	275.0	40.6°	42.8°	39.8°	46.5°	63.58	1.4634
Fairbank's lards	.9095	279.4	38.1°	40.6°	37.4°	57.9°	85.31	1.4651

STATISTICS OF THE LARD INDUSTRY.

It was developed in the investigations before the Committees on Agriculture of the Senate and House of Representatives that the annual production of lard in the United States is 600,000,000 pounds, of which about half is pure lard and the other half pure lard mixed with stearine and cotton oil, the "refined" or compound lard of commerce. The annual exports of lard are about 320,000,000 pounds, of which about 40 per cent. were compound or refined lard.*

According to the figures furnished by the Bureau of Statistics the production of lard from 1877 to 1887, inclusive, is as follows:

Years.	Total.	Years.	Total.
	Pounds.		*Pounds.*
1886-'87	527,032,000	1881-'82	468,929,000
1885-'86	514,230,000	1880-'81	517,660,000
1884-'85	480,405,000	1879-'80	479,020,000
1883-'84	444,450,000	1878-'79	514,295,000
1882-'83	419,513,000	1877-'78	404,572,000

The exports from 1873 to 1888 are shown by the following numbers:

Years.	Lard exported.	Years.	Lard exported.
	Pounds.		*Pounds.*
1873	234,901,511	1881	335,001,686
1874	184,100,226	1882	239,904,657
1875	167,579,377	1883	273,236,610
1876	198,008,212	1884	228,165,733
1877	237,744,307	1885	301,305,105
1878	345,693,527	1886	298,083,094
1879	243,119,208	1887	324,515,224
1880	405,437,658		

*Statement of Mr. G. H. Webster before House Committee on Agriculture, report of hearings, p. 26.

If we take the percentage of cotton oil in the compound lard at 40, the total weight of oil used in manufacturing mixed lard is 120,000,000 pounds.

In addition to this large quantities of cotton oil are used for salad dressing and culinary operations, and in the manufacture of a substitute for lard (cotolene) which contains no hog grease whatever.

EXPERIMENTS IN THE MANUFACTURE OF SUGAR.

Assignment of work.—The bill making an appropriation for experiments in the manufacture of sugar did not become a law until the 19th of July, 1888. At that time it was manifestly impossible for the Department to make any arrangements of its own for the conduct of experiments during the present manufacturing season. It was necessary, if any experiments be made at all, that they should be arranged for in connection with work already in progress, either by individuals, private corporations, or State experiment stations. The following arrangements were therefore made for the experimental work:

(1) A continuation of the experimental work at Rio Grande, N. J., under the direction of Mr. H. A. Hughes.

(2) A series of experiments at Kenner, La., under the direction of Prof. W. C. Stubbs.

(3) Experimental work at Douglass, Kans., under the direction of the Douglass Sugar Company.

(4) Experimental work at Conway Springs, Kans., under the direction of Mr. E. W. Deming.

(5) Experiments in the improvement in the varieties of cane at Sterling, Kans., under the direction of Mr. A. A. Denton.

In addition to the above work, arrangements were made for analytical researches under my direction at Douglass, Conway Springs, and Sterling, Kans. It was deemed unadvisable, at the late date mentioned, for the Department to suggest any experimental work or assume any control thereof. Having been authorized to arrange for such work in a manner which seemed most advantageous, the following directions were given: The work at Rio Grande was placed exclusively in charge of Mr. H. A. Hughes, to be conducted in such manner as he saw fit for the benefit of the industry. The work which Mr. Hughes proposed to do was on a small scale, with the ultimate idea of making it possible for farmers and others to manufacture sugar without the expense of apparatus usually considered necessary for that purpose. The results of Mr. Hughes's work have been reported by him further on, and a discussion of them will be given in connection with his report.

Prof. W. C. Stubbs having commenced preparations for experimental work with sorghum at the experiment station at Kenner, he was authorized to complete this work under the auspices of the Department. No instructions in regard to the method of performing the work were sent to Professor Stubbs except to do that which seemed best for the promotion of the industry. His report of the results of the work and the discussion thereof will follow.

The experimental work at Douglass, Kans., was placed under the control of the Douglass Sugar Company. Its object was to test thoroughly the method of open diffusion practiced on a small scale by Mr. Hughes at Rio Grande, and they conducted the work under the general instructions to give that system of diffusion and the appa-

ratus a thorough and impartial test. The general results of the experimental work at the station are given in the report of Mr. Edson, with a discussion of the data there recorded.

The experimental work at Conway Springs consisted in the trial of a new system of preparing the exhausted chips for fuel, and certain new arrangements of apparatus connected with the diffusion battery and of a new system of handling and storing the cane. No specific instructions were given to Mr. Deming in regard to the conduct of the work, but he was left free to use his own judgment in every particular in regard to what was best to be done. Mr. Deming's report and the discussion thereof will follow.

The experimental work at Sterling was of an entirely different order. The Sterling Sugar Company had commenced a thorough examination of all obtainable varieties of the sorghum plant. By an arrangement made with this company the Department assumed this work in the condition in which it was found the latter part of July and carried it to completion under the supervision of Mr. Denton. Mr. Denton's report and observations thereon will follow.

The following assignment of the chemical force of the Division was made for the purpose of securing analytical data of the season's work:

Mr. Hughes having expressed an opinion that he could get along independently of any chemical assistance from the Department, no assignment was made to Rio Grande. Mr. Edson was placed in charge of the chemical work at Douglass, assisted by Mr. John L. Fuelling. Prof. E. A. von Schweinitz was placed in charge of the chemical work at Conway Springs, assisted by Mr. Oma Carr. Dr. C. A. Crampton was placed in charge of the work at Sterling, assisted by Mr. Karl P. McElroy.

In the latter part of July I visited the three localities last named and arranged with the proper persons for the establishment of the laboratories and perfected the arrangements for the chemical control which was desired. In September and October I visited each of the laboratories above mentioned and spent some days with the chemists in charge in consultation concerning the progress of the work and any changes or alterations therein which seemed necessary. The results of the chemical work in each case will be found in connection with the reports of the respective stations.

Experiments at Rio Grande, N. J.—The result of the work at Rio Grande is disappointing in its nature. For some reason the cane grown in that locality has failed to improve, although it appears that it has had the benefit of careful attention and fertilization. There has been upon the whole, as indicated in Bulletin 18, a deterioration of the cane at Rio Grande; the crops which were raised six or seven years ago showing a higher percentage of sucrose than those of the present time. This deterioration has been caused either by admixture of a non-saccharine variety with the seed, by the method of culture or by the influence of the soil and climate of that locality. I am inclined to attribute much of the depreciation to a fault of the seed; whether or not it has been mixed with broom corn I am unable to say. The almost total failure of the Amber cane at Rio Grande would seem to indicate that some such accident had happened to it. While Amber cane in other localities has continued to show a high percentage of sucrose in the juice, at Rio Grande it has become a worthless variety for sugar-making or even the production of sirup. The importance of seed selection is emphasized by this fact, since there is every reason to believe that if seed of the Early Amber, such

as was planted at Rio Grande seven or eight years ago, were again planted in that locality it would produce an equally rich crop of cane. It would be a useless task, however, for any one to attempt the successful manufacture of sugar by any process from juices no richer than those reported by Mr. Hughes during the present year; such cane at best could only make molasses and that probably of an inferior character. These agricultural results are the more discouraging because of the systematic attempts which have been made at Rio Grande in conjunction with the New Jersey experiment station for the production of a high-grade cane; these are not, however, sufficiently discouraging to justify abandonment of similar attempts in other localities. In respect of the climate at Rio Grande I can see nothing which would lead me to believe that it is unfavorable to the growth of sorghum. On the other hand, the climatic conditions appear extremely favorable unless it be true that sorghum will not develop a maximum content of sugar in localities favored with abundant summer rains. Aside from this the favorable conditions for growth and the practical immunity from early frosts render the locality a most favorable one for the production and manufacture of a crop of sorghum cane. The soil of this locality, it is true, is not naturally as fertile as the soils of Kansas, but with the judicious fertilization which has been practiced the tonnage per acre has been fully as great if not greater at Rio Grande than in most other localities.

In regard to the methods of manufacture employed at this station it is necessary to speak with some degree of caution. In the report of Mr. Hughes we have, from his stand-point, a brief but graphic description of the method employed. I have never been of the opinion that sugar-making from sorghum could be successfully practiced on a small scale, and the experiments carried on by the Department of Agriculture for two successive seasons at Rio Grande have only served to confirm me in this belief. The nature of the processes employed, the character of machinery required, and the kind of skilled labor needed, all combine to render the manufacture of sugar on a small scale commercially unsuccessful. I do not see any favorable result in this direction from the two years' trial at Rio Grande.

For the present manufacturing season Mr. Hughes does not give the total amount of sugar made except from a portion of the crop; and this is no evidence whatever that its cost has been sufficiently low to enable it to be put upon the market in competition with other sugars. I should have been glad had the result been otherwise, for the successful inauguration of an era of sugar-making conducted by farmers would have been a great blessing to vast agricultural regions.

In regard to the machinery employed my opinion has already been expressed. I have said repeatedly, both in official publications and in other places, that I regarded the system of cutting and preparing the cane devised by Mr. Hughes, and now in use in every sorghum factory in the United States and in at least one cane-sugar factory, as the very best which has yet been invented. I have long been convinced that for the extraction of sugar from cane of both kinds the greater the degree of comminution of the chips the more successful the process will be. The system of double shredding inaugurated by Mr. Hughes during the past season tends to secure this end. It was in this direction also that I urged last year for sugar cane the construction of a shredding machine on the principle of the shredder

built by the Newell Universal Mill Company of New York, for the purpose of preparing the pieces of cane properly for the diffusion battery. This shredder I suggested should be furnished with very fine steel knives of the general pattern of the shredder now in use, with short cylinders of large diameter driven at a very much higher rate of speed. Last year I suggested to Mr. Fiske, the inventor of the machine above mentioned, the advisability of building such a machine in duplicate for the purpose of reducing the cane to as fine pieces as possible. The advantage of such a shredder as this over the one used by Mr. Hughes would be principally in its greater strength and in the assurance that it could be run for days, and perhaps a whole season through, without any necessity for repairs. It is of the highest importance that the apparatus for cutting and pulping the cane should be as effective as possible and built in two sets, so that if one should be out of order the second could still be used.

In regard to the system of diffusion practiced at the Rio Grande station and described in Bulletin 18, further experience only leads me to emphasize what has been said in that bulletin, viz:

> The defects of the system were both mechanical and chemical. The mechanical difficulty is the same as that which attends all methods of diffusion in which the cane chips are moved instead of the diffusion liquors. From a mechanical point of view, it is far easier and more economical to move a liquid in a series of vessels than a mass of chips. In the Hughes system the whole mass of chips undergoing diffusion, together with adhering liquor, and baskets and suspending apparatus, are lifted vertically a distance of several feet, varying with the depth of the diffusion tanks, every few minutes. The mechanical energy required to do this work is enormous, and with large batteries the process would prove almost impossible.

The truth of this view will be further illustrated in the report of the Douglass Sugar Company. For very small batteries working only a few tons a day this system might possibly be employed, but I doubt even then if it could be economically worked. This opinion of mine, as will be seen, is at total variance with that expressed by Mr. Hughes, and those who propose to become practically interested in the matter will have to decide upon the merits of the two systems of diffusion after a personal investigation.

Mr. Hubert Edson, who has had two years' experience with the open system of diffusion, made the following statements relating thereto in the *Louisiana Planter and Sugar Manufacturer* of December 1, 1888.

This report refers to the battery used at Douglass, Kans., during the season of 1888:

> The battery was built from plans secured directly from Mr. Hughes, and with one or two slight changes was worked throughout the season. The main battery consisted of ten cells, open at the top to admit the baskets in which the chips were placed for diffusion. These baskets, made of strong boiler iron, were attached to the arms of a crane, which was raised, rotated, and lowered till the requisite number of immersions was obtained. Besides these ten cells there was an extra one of the same dimensions placed just outside and within reach of the arms from the larger crane. This arrangement was intended to secure a dense diffusion juice, allowing, as the diffusion progressed, the heaviest juice from two of the cells of the main battery to be drawn into the outside cell, and which there received two baskets of fresh chips before being emptied.
>
> This manner of operating the battery will, it is claimed by the inventor, give a juice almost as dense as a corresponding mill juice. In my opinion, however, no greater advantage is secured by the eleventh cell being outside the main battery than by the same number arranged in regular order. Certainly, at Douglass, the results claimed by the inventor were not even approximated. The outside cell also entailed an extra amount of labor in transferring the basket from the small crane to which it was attached during its immersion to the large crane of the main battery.

So much for the manner of working the battery. Now for the things that are of actual value to the sugar planters—the results obtained and the expenses incident to such results.

Machinery of any kind to be effective should require a minimum of human labor. Let us see how the Hughes battery compares with the ordinary form. At Douglass the battery was designed to work a hundred tons of cane daily, and to do this at least eight men were necessary to shift the baskets to their different places. Half of this number would run a closed battery and find the work easier, since they would have no baskets weighing a thousand pounds each to handle.

Besides this manual labor the whole ten baskets had to be raised every time one was filled or emptied. A large hydraulic pump is used for this work and of itself requires more power than is necessary to run a battery of closed cells. This extra power and labor would not necessarily condemn the apparatus, if such superior results were obtained as to overcome the expense. But instead of this exactly the reverse was accomplished. Not much better extraction was secured than is obtained by the ordinary cane-mill of Louisiana, and this only with a dilution of nearly 50 per cent., causing an extra expense of no small amount of evaporation. Then also the quality of the juice obtained was extremely poor. The almost constant exposure to the air and especially in iron vessels blackened it to such a degree that no good sugars could be made from it. Clarification was nearly impossible with any of the ordinary re-agents in the sugar-house. This was extremely unfortunate in Kansas, as the greatest profits are made on material sold to the home market.

Experiments at Kenner, La.—As has been mentioned before, Prof. W. C. Stubbs was placed in charge of the experiments which were arranged for in connection with the Louisiana sugar experiment station at Kenner and the stations at Baton Rouge and Calhoun. For two previous seasons Professor Stubbs had made extensive experiments with sorghum, which are fully reported in the bulletins of the Louisiana experiment station and in Bulletin No. 18 of this Division. A study of the analytical data of the three years' work in Louisiana shows in an emphatic way the peculiarities of sorghum which have rendered so difficult the successful inauguration of sugar-making from that plant. The great variations in the content of sucrose in the juices of the plant, its susceptibility to injury by storms and other unforeseen causes, are strikingly set forth in the analytical figures which follow. In my opinion the production of a variety of sorghum cane suitable to the soil and climate of the sugar lands of Louisiana will be a work of no small difficulty. From the results of the work already done, and especially during the last year, an account of which is contained in the appended report of Professor Stubbs, it is clearly seen that a season which has produced a sugar cane very rich in sucrose in the State of Louisiana has produced a sorghum crop which is absolutely worthless for sugar-making for commercial purposes. Another point illustrated by the report is brought out in reference to the past work of the station in which, although a cane was produced whose juice was reasonably rich in sucrose, its practical working in the sugar factory was found most difficult. In the report this is ascribed to the presence of large quantities of dextrine or dextrine-like bodies supposed to be derived from the starch originally present in the juice. It is the opinion of Professor Stubbs that starch and sucrose are developed in the sorghum *pari passu*. In this case it would be found that the direct polarization of a sorghum juice rich in sugar would show apparently a much higher content of sucrose than was actually present, since dextrine and its allied bodies are much more dextrogyratory than sucrose. The points developed by the experiments may be summarized as follows:

(1) Sorghum cane develops sometimes in Louisiana a juice containing a very high percentage of sucrose, but combined with other bodies which render its separation from the juice difficult.

(2) The occurrence of a wet summer attended by the severe wind storms which are so common in that locality prevents the development of a high sucrose content in the growing sorghum.

(3) The possible utilization of sugar machinery for a longer manufacturing season is one of the chief inducements in the sugar-cane regions for the cultivation of sorghum as a sugar-producing plant.

(4) Delay in working the cane after cutting is not as dangerous as has been supposed.

It will be understood that these are conclusions which I have drawn from reading Professor Stubbs's report, and are not formulated in the above manner by himself. Some of these conclusions do not seem to me to be justly drawn from the data at hand.

The results of the attempts to grow sorghum for sugar-making purposes on the low sugar lands in Louisiana in my opinion are not highly encouraging to the belief that these lands and their climate are the best suited in the United States for the production of sorghum as Professor Stubbs says. On the other hand I believe there are few localities in the United States where sorghum grows at all in which a better crop for sugar-making purposes can not be produced. Experience has shown that the dry climate of southern and western Kansas produces the most uniform crop of sorghum for sugar-making purposes, while the data of Professor Stubbs which follow show that the Louisiana product, for the present year at least, is about the poorest on record. One point, however, should be borne in mind, viz, that the course of experiment pursued by the Louisiana experiment station is the one which is best suited for the rapid development of every possibility of sorghum culture in that State. The experimental trials which are made with sorghum will show both its weak and strong points, and in the wide variation which the plant shows there will doubtless be some variety produced or found which will be best suited to the peculiar conditions which obtain in that locality. The soil and climatic conditions of the northern part of the State where cotton is now grown will probably be found better suited to the production of sorghum than those of the present sugar-producing localities. I feel quite sure that the expectation expressed by Professor Stubbs of being able to realize under certain conditions as much as 120 to 125 pounds of sugar from sorghum cane may be fully met under favorable circumstances ; but it would still remain to be demonstrated that this yield could be reasonably expected from year to year or even occasionally on a large scale. The subsequent experiments which are promised by Professor Stubbs at the Louisiana station will doubtless set at rest, in a few years, all these questions and demonstrate to the sugar-makers of Louisiana just what can be expected from sorghum as an adjunct to their great industry.

Experiments at Conway Springs.—In the reports of Messrs. Deming and Von Schweinitz, which follow, together with the analytical tables,* much interesting information may be found in regard to the sorghum-sugar industry in Kansas. The successful continuation of the work at Fort Scott has encouraged the belief in the possibility of a speedy establishment of a sorghum-sugar industry in Kansas on a large scale. The unfortunate financial outcome of the work, however, at Conway Springs shows that much is yet to be learned by those entering upon this industry before success can be confidently predicted. A discussion of the chemical data collected at Conway Springs will be found in connection with the analytical tables. It is

* See Bull. No. 20.

proper to say here, however, that the sorghum juices of the crop grown at Conway Springs show a higher content of sucrose than any large crop which has ever before been produced in the United States. This high content of sucrose, which appeared in the crop after the middle of September, as indicated by the analysis of the juices, was continued until the close of the working season in November. The samples of chips taken from the cells of the battery showed in their juices a high content of sucrose uniformly; much higher, in fact, than would be indicated by the output of sugar. One reason, doubtless, for this was the exceptionally dry season diminishing the content of water in the cane, and thus increasing the percentage of sucrose in the juice. This fact, though not established by the determination of the fiber in the cane, is plainly indicated by two other facts developed by the analytical work, viz, the diminished extraction when using the small mill of the same pressure as the season progressed and the high content of total solids in the juices. The output of sugar was evidently diminished by the character of the water used in diffusion; but that would be unable to account for the small yield of crystallizable sugar obtained with juices of the richness of those worked. Experiments made by boiling a solution of pure sugar with the water used in diffusion at Conway Springs proved that the presence of a large amount of gypsum did not tend to increase the inversion of sucrose; that it may, however, have interfered with the crystallization of the sucrose is a fact which can scarcely be denied. The actual output of sugar at Conway Springs in my opinion would have been considerably larger had pure water been employed in the diffusion battery; nevertheless the important fact remains that the yield of crystallizable sugar was wholly disproportional to the richness of the juices worked, showing that the high ratio of sucrose was not obtained at the expense of the solids not sugar in the juices. In other words, it appears that a cane whose juice is normal in quantity, say at about 90 per cent. of the total weight, and having a content of sugar equal to 10 per cent., with total solids at 16 per cent., will yield fully as much if not more sugar than a cane whose juice is abnormal, say not more than 80 per cent. of the total weight, with 12 per cent. of sucrose and 18 to 20 per cent. of total solids. Another important fact developed by a study of the data obtained at Conway Springs is in the persistence of the sugar content in the juice after the cane was fully ripened. In localities where considerable moisture may be expected in the soil as a result of frequent rains during the manufacturing season it has been noticed that there is a rapid deterioration of the juices beginning a short time after complete maturation. This has been especially noticed in the experience at the Rio Grande station. It has also been noticed by all careful observers of the sorghum grown in ordinary localities. The inspissation of the juices by the natural causes of an extremely dry climate appears to protect the sugar from this destruction. This is a point of the greatest interest to sorghum-growers; to whom the preservation of the sugar in the juice for a reasonable length of time is a matter of the greatest consideration. In the process of diffusion this thickening of the juice entails no loss, although if milling were used for expressing the juice the loss would be a most serious one. The above explanation of the character of the juice at Conway Springs is offered with some degree of hesitation, since I am fully aware of the danger of drawing conclusions in sorghum work from a too limited number of observations.

The manufacturing operations at Conway Springs were greatly hindered by faults in the machinery which could scarcely be avoided when the short time allowed for the manufacture and erection of the same is considered. Instead of taking three months for the erection of a sugar factory a whole year is none too long a time, and disaster, for at least one year, is certain to attend attempts to erect such machinery in the time allowed at Conway Springs.

What is needed now in the sorghum-sugar industry is the manufacture of sugar at a rate which will enable the manufacturer to compete with sugar from other parts of the world. A great step in this direction will be secured when the kind of machinery which has been pointed out by the investigations of the Department as necessary to success shall be constructed by skilled machinists and erected by skilled engineers with time enough at their disposal to finish their work before the manufacturing season begins. Some further remarks on this subject will be made in another place.

From a commercial point of view the results of the work at Conway Springs are wholly disappointing; to the person, however, who will take pains to inform himself in regard to the conditions which there obtained many points of encouragement will be found in spite of the financial failure of the first season's work.

Experiments at Douglass, Kans.—The practical experiments carried on at Douglass consisted in a thorough trial of the open system of diffusion (the Hughes system) to test its fitness for working on a large scale. For the details of the construction of the battery I refer to the report of Mr. Edson. In regard to its working in general I may say that it was a total failure both as to economy of power and success of extraction. The financial difficulties which were encountered by the company during the year were attributed largely to the use of this battery. The evaporating apparatus in use at Douglass was of first-class quality and arranged in a practical manner. The system of clarification tanks, double effects, and strike pan was as good as could be desired for sugar-making purposes. Had the company adopted the system of diffusion erected by the Department at Fort Scott there is every reason to believe that even during the first season it would have paid all expenses and made a reasonable profit. The attempt to introduce a new and untried system on a large scale shows the danger which too often besets the introduction of a new enterprise. The promoters of such an enterprise, not satisfied with what has been accomplished, attempt to follow new paths which often lead to unknown and unwished-for localities. It is best in any enterprise to accept what has been proved of value and not jeopardize the success of a commercial undertaking by introducing in its place a kind of experiment which, failing, would destroy all prospects of success. As will be seen by the analytical tables accompanying the Douglass report* the crop was of fair quality, showing about the average percentage of sucrose developed in Kansas during the last two or three years. The soil on which most of the crop was raised was somewhat richer in vegetable matter and contained less sand than the soil at Conway Springs. The climatic conditions of the two places were so nearly identical as to make apparently but little difference, yet it must be conceded that at Douglass the hot, dry winds produced less effect than at Conway Springs. There did not appear to be the same drying up of the juice, which may account to some extent for the per-

* See Bull. No. 20.

centage of sucrose therein being less. The agricultural results, however, were of the most encouraging nature, showing that in this locality a crop of sorghum cane can be grown which with proper treatment may be expected to yield from 80 to 90 pounds of sugar per ton of clean cane. Not only were the actual results rendered unfavorable by the kind of battery employed, but aside from this for some reason the centrifugals used proved to be wholly inadequate to the severe task imposed upon them. The drying of sorghum sugar is at best a difficult task and only the best approved centrifugal apparatus should ever be employed for this purpose. Had the battery at Douglass worked successfully much delay would have been experienced in the manufacture of the crop by the imperfections above noted in the centrifugal machines.

Experiments at Sterling, Kans.—At the very beginning of my connection with the experiments in the manufacture of sugar from sorghum I realized the importance of improving the quality of the cane to be used. In Bulletin No. 3, page 107, I made the following statements:

The future success of the industry depends on the following conditions, viz:

(1) A careful selection and improvement of the seed with a view of increasing the proportion of sucrose.

(2) A definition of geographical limits of successful culture and manufacture.

(3) A better method of purifying the juices.

(4) A more complete separation of the sugar from the canes.

(5) A more complete separation of the sugar from the molasses.

(6) A systematic utilization of the by-products.

(7) A careful nutrition and improvement of the soil.

Improvement by seed selection.—I am fully convinced that the Government should undertake the experiments which have in view the increase of the ratio of sucrose to the other substances in the juice. These experiments, to be valuable, must continue under proper scientific direction for a number of years. The cost will be so great that a private citizen will hardly be willing to undertake the expense.

The history of the improvement in the sugar beet should be sufficient to encourage all similar efforts with sorghum.

The original forage beet, from which the sugar beet has been developed, contained only 5 or 6 per cent. of sucrose. The sugar beet will now average 10 per cent.* of sucrose. It seems to me that a few years of careful selection may secure a similar improvement in sorghum.

It would be a long step toward the solution of the problem to secure a sorghum that would average, field with field, 12 per cent. sucrose and only 2 per cent. of other sugars, and with such cane the great difficulty would be to make sirup and not sugar. Those varieties and individuals of each variety of cane which show the best analytical results should be carefully selected for seed, and this selection continued until accidental variations become hereditary qualities in harmony with the well-known principles of descent.

If these experiments in selection could be made in different parts of the country, and especially the various agricultural stations and colleges, they would have additional value and force. In a country whose soil and climate are as diversified as in this, results obtained in one locality are not always reliable for another.

If some unity of action could in this way be established among those engaged in agricultural research much time and labor would be saved and more valuable results obtained.

In a summary of the methods which I have advocated for the improvement of the sorghum plant I said in an address before the National Sugar-Growers' Association, in Saint Louis, in February, 1887, that—

Finally our experiments have taught us that after all the mechanical difficulties which have been enumerated in the manufacture of sugar from sorghum have been overcome, the industry can not become commercially successful until the scientific

* In the six years which have passed since the above was written the sugar beet has been still further improved and will perhaps show 12 per cent. of sugar.

agronomist succeeds in producing a sorghum plant with a reasonably high and uniform content of sucrose and a minimum of other substances. This work is peculiarly the function of our agricultural experiment stations. In beet-sugar producing countries the production of the seed for planting is a distinct branch of the industry. So, too, it must be with sorghum. A careful scientific selection of the seeds of those plants showing the best sugar-producing qualities, their proper planting and cultivation, a wise choice of locality and soil, a proper appreciation of the best methods of culture, these are all factors which must be taken into consideration in the successful solution of the problem.

It was with this purpose in view that I made the arrangements with the Sterling Sirup Company by which the Department assumed control of the experiments which they had made in the cultivation of different varieties of sorghum. At the time this arrangement was made, viz, in the latter part of July, Mr. A. A. Denton was already in charge thereof for the Sterling Sirup Company, and he was appointed by you to continue in general charge under the direction of the Department. It was arranged with Mr. Denton that the general line of research should be such as is indicated in the above statements for the purpose in view. The chemists who were sent to take charge of the analytical work were instructed to co-operate with Mr. Denton in such a way as to secure favorable results and to make such suggestions as might seem valuable in the details of the work. Mr. Denton was requested to make a general study of the growth of the different varieties and of the habits of each one with reference to its fitness as a sugar plant. The most promising individuals of each variety were to be selected for experimental purposes and those showing the highest content of sucrose with the lowest content of other substances were to be preserved for future planting. The able manner in which Mr. Denton accomplished this work, assisted by the chemists of the Department, will be found in his detailed report. I regard it of the highest importance to the future success of the industry that the line of work thus commenced by the Department should be continued.

One great difficulty with which we have to contend is in the character of the appropriations made for the experimental work. I have called attention to this difficulty in former reports, and I wish to emphasize the matter here. The fiscal year in all Government affairs begins on the 1st of July. For investigations in agriculture no more unfortunate be inning of the year could be selected. On the 1st of July it is too late to commence experiments for that season; if these experiments be postponed until the next season arrangements can be made for their continuation only up to the 1st of next July, and thus they have to be stopped before they are well begun. The difficulty is extremely manifest in the present instance. The wisdom and value of continuing the experiments at Sterling last year will be denied by no one. Abundant funds are left over from the present year's appropriation to continue the experiments for another season. It is, however, unwise to make any arrangements for such work, since no part of it, except that which will be let out by contract, could be continued after the 1st of July, 1889. You thus find your hands tied, as it were, by the unfortunate disposition of the experimental year, which has to begin and end with the fiscal year. To avoid this difficulty, which has been one of the greatest causes of the disasters which have attended our experiments with sorghum, I earnestly recommend that all appropriations for field and manufacturing experiments in agricultural matters be made to take effect from the 1st of January each year instead of the 1st of July.

POINTS TO BE CONSIDERED IN BUILDING A FACTORY.

It is of the utmost importance, both for the individuals and the industry, that intending investors in the sugar business should carefully consider the problem presented to them in all its forms. Failure is not only a personal calamity but a public one, in that it deters capital from investment in an industry which, properly pursued, gives promise of a fair interest on the money invested.

Soil and climate.—The importance of soil and climate has already been discussed. In the light of present experience it must be conceded that a soil and climate similar to those of southern and western Kansas are best suited to the culture of sorghum for sugar-making purposes. Further investigations may show that Texas and Louisiana present equally as favorable conditions, but this yet awaits demonstration. Conditions approximately similar to those mentioned can doubtless be found in Arkansas, Tennessee, North Carolina, and other localities. The expectations which were entertained and positively advocated a few years ago of the establishment of a successful sorghum industry in the great maize fields of the country must now be definitely abandoned. He who would now advise the building of a sorghum-sugar factory in northern Illinois, Indiana, Iowa, or Wisconsin would either betray his ignorance or his malignity. A season of manufacture, reasonably certain for sixty days, is an essential condition to success in the manufacture of sorghum sugar. Early frosts falling on cane still immature, or a freezing temperature on ripe cane followed by warm weather are alike fatal to a favorable issue of the attempt to make sugar. Sober and careful men will not be misled by the claims of the enthusiast, by the making of a few thousand pounds of sugar in Minnesota, by the graining of whole barrels of molasses in Iowa. Four or five million acres of land will produce all the sugar this country can consume for many years, and these acres should be located where the climatic conditions are most favorable. During the past season sorghum cane matured as far north as Topeka, but in 1886 the cane crop at Fort Scott was ruined by a heavy frost on the 29th of September and in 1885 a like misfortune happened at Ottawa, Kans., on the 4th of October. These interesting facts show that these points are on the extreme northern limits of safety for sorghum-sugar making, and the region of success will be found to the south and west of them.

Natural fertility of soil must also be considered as well as favorable climate. The sandy pine lands of North Carolina can not hope to compete with the rich prairies of southwestern Kansas and the Indian Territory. Indeed, in my opinion, the last-named locality, should it ever be opened to white settlers, is destined to be the great center of the sorghum-sugar industry. Nevertheless, those who plant the virgin soils of this great Southwestern empire must remember that to always take and never give will tire the most patient soils, and a just return should be annually made to the willing fields. A judicious fertilization, rotation, and rest will not only preserve the natural fertility of the fields, but give even a richer return in the improved quality of the cane and the greater tonnage secured. Perhaps the most sensible solution of the problem of the disposition of the waste chips will be found in returning them to the soil. These chips have a positive manurial value in the nitrogen they contain, while their merely physical effect on the soil may prove of the highest importance.

Water supply.—The misfortunes which have attended many attempts in the manufacture of sugar by diffusion, by reason of an imperfect or insufficient water supply, are a sufficient warning on this subject to the careful student. Not only should the water supply be abundant and easily accessible, but the portion of it at least which is to be used in the battery should be as pure as possible. The presence of carbonate of lime and other carbonates in water is not injurious, but the evil effects of a large amount of other kinds of mineral matter are shown in the data from Conway Springs. When the supply of water is insufficient it has been customary to use ponds for receiving the waste from the factory, so that it may be used again. This method is applicable, if care be taken to prevent organic matters, scums, etc., from entering the water supply. In case this precaution is not taken the operator of the factory may find himself in the condition in which the Department was placed in its first experiments at Ottawa and Fort Scott, in being compelled to use water foul and putrescent. It is scarcely safe to rely upon a well for a supply of water, especially if it have to be sunk to any depth. Where pumping machinery must be placed many feet below the surface, as in the cramped condition which attends its erection in a well, serious difficulties may arise from the machinery getting out of order, and a great loss of energy may ensue from the necessity of lifting the water to a great height. In all cases where it is possible a running stream of water should be selected for the supply and the factory should be placed conveniently near its banks. The importance of this matter is emphasized the more when it is considered that the most favorable localities for sugar making, as indicated by the present state of our knowledge, are situated in regions where the water supply is notably deficient; yet it must be admitted that even in southern and western Kansas it will not be difficult to find localities for the erection of sugar factories where the water supply is certain and abundant. In the light of past experience it is not probable that any further mistakes will be made in this direction. Careful estimates should be made of the quantity of water required and absolute certainty should be secured of the supply of that amount of water and even of a much greater amount in cases of emergency. The only safety will be found in some such plan as this.

Proximity of cane-fields.—Another point which must be taken into consideration in the location of a factory is the distance which the cane is to be transported. This is a matter which of course the farmers raising the cane are more interested in than the proprietors of the factory, when the cane is grown by contract. With good roads, in a level country, it is easy to draw from 1½ to 2 tons of field cane at each load. The average price which is paid for such cane at the present time is $2 per ton. It is evident that at a given distance, varying according to the price of teams and labor in each locality, the cost of transportation would equal the total receipts for the cane; in this case the farmer would have nothing left to pay for the raising of the cane and profit. Evidently true economy, from an agricultural point of view, would require the cane to be grown as near the factory as possible. It would be well, indeed, if all the cane could be grown within a radius of a mile from the factory. This would give, in round numbers, 2,000 acres tributary to a factory. With an ordinary season this ought to produce 20,000 tons of cane. The lengthening of the radius of this circle by one-half mile would give the greatest distance to be hauled 1½ miles, thus vastly increasing

the surface tributary to the central factory. It is true that at the present time farmers are easily found who are willing to draw their cane 4, 5, and even 6 miles, but this condition of affairs can not be continued when the business is fully established and the factories in sharp competition with each other. In case the exhausted chips are to be returned to the soil as fertilizer the importance of a centrally located factory as described is doubly emphasized.

Fuel.—A cheap and abundant supply of fuel is not less important than the raw material to be manufactured into sugar. As far as the sorghum-sugar industry is concerned the coal which is used for fuel is transported almost exclusively by rail. In locating a factory, therefore, both for convenience of shipping the product and for receiving a supply of fuel, it should be placed sufficiently near a railway line to enable it to be connected therewith by a switch. It is better, however, that the switch should be of some considerable length than that the water supply should be remote or the cane in distant fields.

The problem of burning the exhausted chips has not yet been successfully solved and I doubt very much whether it will be.* Save the softening which the chips undergo in the process of diffusion the difficulty of expressing the water from them is as great as that of expressing the juice from fresh chips. Thus to dry the chips sufficiently to make them economical for fuel would require a vast expenditure of power which would hardly be supplied by the increased supply of steam generated by their combustion. Experiments during the season of 1887–'88 at Magnolia plantation, Louisiana, showed that an ordinary cane-mill was poorly adapted to the pressure of exhausted cane chips. The feeding of the mill was difficult and the amount of fuel produced seemed wholly disproportional to the expense of preparing it. It has been proposed to try the process used for extracting the water from beet pulp for the purpose of drying sorghum chips. There is nothing whatever in the experience of the beet-sugar factories to warrant the belief that such a process would render the chips sufficiently dry to burn. Although I would not be considered as discouraging any further attempts in the direction of preparing sorghum chips for fuel, I must be allowed to express the belief that for some time to come coal must be relied upon solely for this purpose.

If the chips are to be successfully burned in the future, we may make up our mind that it will have to be done by previous pressure in mills which in all their appointments shall be as strong and efficient as those which have been in use for expressing the juice from cane. It can not be hoped that these chips will be made sufficiently dry by exposing them to the sun, and in artificial desiccation the amount of fuel required would be almost as great as that used in the evaporation of the original juice. It is claimed that at Wonopringo, in Java, as reported in the *New Orleans Item* of December 16, 1888, the Fives-Lille Company has succeeded in drying the chips by passing them through two powerful three-roll mills; and that the chips thus dried do not contain more than 55 per cent. of moisture and burn readily in an automatic furnace invented by Godillot. If it be assumed that 100 pounds of chips contain 10 pounds of combustible matter it is seen that nearly 80 pounds of water will have to be expressed therefrom before they are fit for fuel. I am doubtful

* Experiments made since the above was written seem more favorable to the successful burning of the chips.

whether such a process will prove profitable save in countries where fuel is very dear as it is in Java and Cuba.

Cost of factory.—It is an almost universal experience that the actual cost of a sugar factory is underestimated by those who undertake its erection. Many of the disasters which have attended the manufacture of sorghum sugar have been due to a miscalculation of the cost of the apparatus necessary for the purpose. It is the part of wisdom to avoid mistakes of this kind, and before undertaking the erection of a factory to fully understand the amount of outlay which will be required. The cost of a factory will of course vary according to its capacity and the character of the machinery and building erected. In my opinion there is little economy in using cheap machinery, hastily and poorly put together. Success is more likely to be obtained by using the very best machinery which has been devised for sugar-making purposes, and erecting it in a lasting and substantial manner. The economy which is secured in operating such machinery far exceeds that which would be obtained by erecting a cheaper plant. The character of the plant must also be taken into consideration; it should be sufficiently large to allow a proper distribution of all parts of the machinery without crowding, and sufficiently strong to afford a proper support for such portions thereof as may rest upon it. Due regard should also be paid to risks of fire, and that portion of the factory especially exposed to such dangers should be made as nearly as possible fire-proof. The plans and specifications for all the machinery should be carefully prepared under the direction of a competent engineer and architect, and the machinery furnished by manufacturing firms whose experience and reputation are a guaranty of the excellence of their work. For a complete factory capable of working 200 tons per day the cost may be estimated at $60,000 for a minimum and $100,000 for a maximum, the difference being caused by the elaborateness of the work. This may seem a large sum, but it is highly important that intending investors should know the magnitude of the undertaking which they propose. An estimate which exceeds the actual outlay by $10,000 will be far more satisfactory to all parties concerned than one which falls short of it by the same amount.

Technical and chemical control.—The manufacture of sugar from sorghum is no mysterious process known only to one or two persons as attempts have been made to establish; nevertheless, it must be understood that without experience in the manufacture of sugar the most competent engineer may fail. It is best, therefore, that intending investors understand this beforehand that they may be able to secure some one to take charge of the manufacture of sugar who thoroughly understands the needs of the business and has had some experience in the conduct thereof. Perhaps there are not more than fifteen or twenty such men now in the United States, but their number will be largely increased within a short time. It would seem, therefore, that the number of factories which could be successfully operated in the next year or two is limited, and this fact should be taken into careful consideration by those intending to invest money in the business. An intelligent young man of good education, with quick perceptions and of industrious habits, would be able in one year, with a sorghum-sugar factory, to obtain a knowledge which would enable him to take charge of a factory with some degree of success on his own responsibility. One object which the Department has had in view in its experiments has been in having them open not only to public inspection but to careful technical study to

such persons as chose to make the attempt. It is to be regretted that at least one company, who, through the courtesy of the Commissioner of Agriculture, was permitted to use a large amount of machinery belonging to the Department, have so far forgotten their obligations to the public as to refuse permission for a technical study and report on their operations during the past year. Public property is devoted to a poor purpose when used in such a manner.

The importance of chemical control of the manufacturing work is so evident that I need not dwell upon it long. The vagaries of the sorghum plant are so pronounced as to require the careful supervision of the chemist at all times. In localities not far removed differences in the character of the sorghum are most marked, as illustrated by the data obtained at Conway Springs and Douglass, Kans., during the past year. To determine the fitness of the cane for the manufacture of sugar, control the workings of the factory, and find and remove the sources of loss in the sugar-house are duties which can be committed only to the chemist. For many years at least this chemical supervision will be necessary and its utility will always continue.

PROGRESS OF DIFFUSION WITH SUGAR CANE.

Two plantations are using the process of diffusion during the present season for the extraction of sugar from sugar cane. These are "Sugar Land" plantation of Colonel Cunningham in Texas, and the Magnolia plantation of Governor Warmoth in Louisiana. The latest reports from the "Sugar Land" plantation I found in the *Item* of December 15, 1888. At that time it is reported that over 2,000,000 pounds of sugar had been made and the diffusion battery was working up from 300 to 350 tons of cane a day. It is also reported that an average of 194 pounds of sugar is made per ton. From the analyses of the cane reported in the *Item* of November 28, 1888, it appears that the juice has about 12 per cent. of crystallizable sugar. The success of the operation seems to be fully assured.

The working of the battery at Magnolia is also satisfactory. The analysis of the cane shows that it is extremely rich in sugar. In the *Item* of December 4, it is reported that the juice contained 13.7 to 16.6 per cent. of sugar. A polarization had been made showing as high as 19.2 per cent.

Under date of December 9, Mr. G. L. Spencer writes as follows:

> Diffusion is working to every one's satisfaction. We have had a great many delays, almost all of which were caused by the Yaryan quadruple-effect pan. Governor Warmoth had the apparatus overhauled this morning and found that the exhaust pipe from the pump opens into the second effect, making a pressure pan of this when working with more than 3 or 4 pounds of steam. This defect has been remedied and we hope everything will be all right now. The cutter gave a great deal of trouble at first, so much that we thought it would be necessary to abandon it. Finally two holes cut in the side of the casting opposite the cutting disk relieved it, so now it is working well. We can cut a cell of chips averaging 2,864 pounds in seven and one-half minutes. The dilution will probably surprise you. I intended starting with a dilution of 33 per cent., but by a mistake in measurement I started with 50 per cent. With 50 per cent. dilution we left from .28 to .70 per cent. sucrose in the chip juice. I gradually reduced the dilution until it dropped to 14.8 per cent., leaving about .70 to 1 per cent. of sucrose in the exhausted chip juices. We have finally commenced running with a dilution of 21 per cent., leaving .42 per cent. of sucrose in the exhausted chip juices. With pulped cane, such as Hughes's apparatus gives, I would be willing to guaranty a dilution of only 18 per cent. and to leave less than .50 per cent. of sugar in the exhausted chips. We tried the use of lime in the cells. Practically when making white sugar we can not work the battery hot enough to obtain clean juice. We try to keep the battery at about 90° C.

Further experiments have also been in the application of diffusion to sugar cane by Prof. W. C. Stubbs at the Kenner sugar experiment station. A full report of this work will be published in a forthcoming bulletin of that station. In the *Louisiana Planter and Sugar Manufacturer* of December 1, 1888, a report is found on a part of the work done. As high as 240 pounds of sugar have been obtained per ton of cane. The results of the work are in every way encouraging.

From the above it is seen that diffusion with sugar cane is an assured success and we may expect to see it gradually displacing the milling process throughout the sugar-producing world.

The use of lime in the diffusion battery.—The use of carbonate of lime in the diffusion battery and the patent obtained for this process by Prof. Magnus Swenson are fully discussed in Bulletin No. 17, pp. 61 *et seq.*

Since the publication of this bulletin and Bulletin No. 14, further experiments at Conway Springs have demonstrated that the method originally proposed by me for the use of lime to prevent inversion in the battery by evenly distributing finely divided lime upon the fresh chips has proved satisfactory. An apparatus constructed by Mr. E. W. Deming succeeded fairly well in evenly distributing over all the chips entering the cell the lime in such fine state of division as to prevent any portion of the contents of the cell from becoming alkaline. The lime was prepared by air slaking and sifting through a fine sieve into a barrel covered by a cloth to protect the laborer.

During the past year the use of lime in the diffusion battery for clarifying the juices has received a good deal of attention. The first person who proposed this process and took out a patent upon it was Mr. O. B. Jennings. Letters patent No. 287544, dated October 30, 1883, were issued to Mr. Jennings on an application filed on the 2d of April, 1883. Following is an abstract of Mr. Jennings's patent:

Be it known that I, Orlando B. Jennings, of Honey Creek, in the county of Walworth and State of Wisconsin, have invented certain new and useful improvements in the manufacture of sugar from sugar-cane, sorghum, maize, and other plants of which the following is a full, clear, and exact description:

This invention relates to the manufacture of sugar from different sugar-producing plants, including sugar-cane, maple, sorghum, and maize; but it has more especial reference to defecating the juice in the stalks of sugar-cane, sorghum, and maize and extracting the juice from the residue or bagasse for subsequent boiling into sugar and sirup.

In making sugar from sugar-producing plants with my invention, it is my purpose to extract and utilize all of the saccharine juice and to obtain entire control of its defecation, so as to make a sirup free from foreign matter and elements of fermentation. By it the juice in evaporating is free from skimmings or precipitates that are always liberated in the ordinary method of extracting, which waste my invention avoids.

Applied to the manufacture of sugar from cane and other stalks the invention consists in a process of preparing said stalks for the more perfect extraction of the juice by reducing the same to a finely-comminuted or dust-like condition, and whereby the juice cells are thoroughly crushed and ruptured. This part of the invention also includes a combination of circular saws, forming a compound saw, for reducing the canes or stalks to such finely-comminuted condition, likewise sprinkling or mixing with said dust, before defecation, dry lime or lime whitewash in powder. Such lime combines with the acid in the dust, and upon suitable application of heat to the whole forms double precipitation at one and the same time.

Furthermore, the invention consists in a process of precipitating the matter in the cane-juice cells and cane pulp, or in the juice of any sugar-producing plant, however obtained, by exposing the juice or material under treatment to a temperature of over 212° Fahr., and subsequently removing the juice from the woody or precipitated matter by washing the same with currents of water. In carrying out

this part of the invention I use a cylinder or other suitable vessel in which the temperature is raised to the required degree (about 212° Fahr.) for defecation and precipitation of the matter capable of being precipitated, whether the same be contained in sugar-cane, sorghum, and maize stalks, reduced to dust or not, or in any saccharine juice, including maple sap, the temperature varying from 228° to 267° Fahr., according to the ripeness of the material under treatment and other conditions. This vessel is suitably constructed or provided with means to admit of the introduction of the material to be treated; also, to provide for the forcing out of the exhausted bagasse or refuse, and for the introduction of steam while and after charging it; likewise, steam to act upon the condensed water and released juice and force them out through a filter. Means are also provided for running the wash water from a series of tanks in succession through said vessel, to act upon the charge therein, and an arrangement of defecating-tank connections for introducing scum, sediment, and sweet wash-water upon a succeeding charge.

In the process of extracting the saccharine matter of cane, the mixing with the comminuted cane, before the passage of the same into the diffusing apparatus and the defecating of the same, of dry lime or lime whitewash, whereby the material will be thoroughly defecated without the liability of the admixture therewith of the precipitate of the lime, substantially as described.

The combination, with the diffusing tank of one or more defecating tanks to which the juice is delivered from the diffusing tank, and pipes provided with valves for drawing the skimmings, settlings, and sweet water from said defecating tank or tanks and passing the same into the diffusing tank or vessel, essentially as and for the purposes herein set forth.

In combination with the defecating tank, diffusing tank, and a suitable evaporator, the settling tank provided with a discharge pipe for running the juice into evaporator, and with means for passing its sediment into the diffusing tank, substantially as described.

It is seen that Mr. Jennings makes a broad claim for the application of the process of clarification in the diffusion apparatus for all sugar-producing plants. Mr. Jennings has claimed that the process devised by the Department for the use of lime to prevent inversion in the battery is an infringement on his method. Any one who will carefully examine Mr. Jennings's claim, as set forth by himself in his application for a patent, will see that the two processes are entirely different not only in principle but in the method of application.

In a letter to the *Rural World*, published on the 13th of December, 1888, I endeavor to make this matter clear. Following is a copy of the letter:

WASHINGTON, D. C., *December* 1, 1888.

Editor Rural World:

I have read in the *Rural World* of the 22d of November the letter from O. B. Jennings, of Grover, Colo., in regard to his patent for clarifying cane juices in the diffusion battery.

Mr. Jennings is laboring under the mistake that I have been using his process and spending five years on what he showed me how to do at first. This is a complete misapprehension of the case. I have never denied to Mr. Jennings the honor of inventing the method of clarifying cane juices in the diffusion battery; in fact, long before his letter in your paper appeared I wrote a note to the *New Orleans City Item*, specifically claiming for him the honor of the invention which had been attributed to another source.

It is important to sugar-makers, either present or prospective, to know the following points, viz:

(1) The process of using carbonate of lime in the diffusion battery is a patented process which can only be used under royalty or by permission of the inventor, Professor Swenson.

(2) The process of clarifying the cane juices in the diffusion battery is a patented process and can only be employed under royalty or by permission of the inventor, Mr. O. B. Jennings, of Grover, Colo.

(3) The use of dry lime or lime in any form in the diffusion battery to prevent inversion is a process devised by the Department of Agriculture and offered free to all sugar-growers in this country. Under proper chemical control it is more efficient than the use of carbonate of lime.

I will say further that I have never tried in any way to use Mr. Jennings's process, since in an ordinary diffusion battery it would be wholly impossible to do so. The high temperature which he requires for the proper clarification of the juices would render the circulation of the liquid in the battery almost impossible.

Respectfully,

H. W. WILEY,
Chemist.

The process of using lime in the diffusion battery for clarifying purposes it is claimed has been successfully practiced in Java and Australia.

Prof. W. C. Stubbs has also used it with success at the sugar experiment station at Kenner, La.

Col. E. H. Cunningham, of Sartartia, Tex., has also used the process with success, as indicated by the following letter from him published in the *Louisiana Planter* of December 1, 1888:

My diffusion battery is now working nicely, and I am very much gratified at the results obtained. Diffusion is a success beyond a doubt. I am now working sugars by running the juice direct from the diffusion cells to the double effects without any clarification, except using a little lime in the diffusion cells.

I shall be glad to have a visit from you or any of your friends who feel an interest in diffusion.

The process of ordinary clarification in my opinion is more favorable to the production of a pure sugar than any form of clarification in the cells of the battery. The process as practiced at Kenner and Sugar Lands, however, differs from that described by Mr. Jennings in working at a lower temperature.

COMPARISONS OF TOTAL SOLIDS DETERMINED BY SACCHAROMETER AND DIRECT DRYING.

During the season of 1887 I instructed the chemists at the Fort Scott station to make a series of comparisons between the total solids as determined by our standard saccharometer and by direct weighing. The desiccations were to be made in flat dishes partly filled with loose asbestos or clean sand. The purity coefficient of the juice as shown by the spindles appeared too low to permit so large a yield of dry sugar. As was expected, the total solids as determined by direct weighing were found considerably less than were indicated by the spindles. The ratio of each variation was not the same, but a large number of determinations established a mean rate of variation which will make it possible to approximately correct the reading of the common spindle. At Magnolia last year similar experiments were made with the juices of the sugar cane, but these were not extensive enough to fix the rate of variation for those juices. Following is a record of some of the work done here:

Comparison of total solids.

No.	Total solids by spindle.	Total solids dried in dish.	Difference.	Total solids in hydrogen.	Difference.
	Per cent.	*Per cent.*		*Per cent.*	
6029	12.60	11.93	.67	....	....
6065	15.20	13.54	.66	....	....
6070	13.20	12.87	.33	....	....
6074	12.20	11.48	.72	10.94	1.26
6075	11.50	11.04	.46	10.84	.70
6076	13.30	12.85	.45	....	....
6079	12.30	11.77	.53	11.59	.71
6081	12.50	12.00	.50	11.65	.85
6083	16.30	16.04	.26	....	....

The determinations in hydrogen were made in a specially constructed apparatus consisting of a glass cylinder furnished with a glass stopper carrying two tubes with stop-cocks for displacing the air with an atmosphere of hydrogen. The juice was absorbed by a dried-paper coil and supported in the cylinder on a disk of wire gauze resting on a lead tripod. The cylinder contained 25 c. c. of strong sulphuric acid. The cylinder carrying the coil was placed in a steam bath filled with dried hydrogen at 100°. The stop-cocks were then closed and the whole apparatus left at the temperature of the steam for five hours. The sulphuric acid absorbed all the moisture, and after cooling and filling the cylinder with dried air the coil was removed and weighed in a closed holder.

The determinations in flat dishes were made by drying 2.5 to 3 grams of the juice at 102° for five hours. Scarcely any difference was noticed between the results given by the plain dishes and those filled with sand or asbestos, except in the work at Conway Springs.

In the determinations made here in plain dishes the percentage of total solids was 4.68 per cent. less than by the spindle. In the determinations in hydrogen they were 6.94 per cent. less. The determinations in hydrogen, therefore, will show 2.26 per cent. less total solids, calculated on the number given by the spindle, than those obtained by drying.

At Douglass, Kans., the normal juice, calculated on the data furnished by the spindle, showed a loss of 8.61 per cent. in total solids when dried in open dishes.

At Conway Springs this loss in plain dishes was 7.24 per cent., and in asbestos 8.23 per cent.

With diffusion juices these losses were for Douglass, 11.34 per cent., and for Conway Springs, 9.67 per cent. in plain dishes and 10.83 per cent. in asbestos.

The mean loss for normal juices at Douglass and Conway Springs was 8.36 per cent.

For the diffusion juices the mean loss was 10.61 per cent.

It appears, therefore, that a saccharometer of the standard Brix variety as standardized by pure cane-sugar solution must be corrected by fully 10 per cent. of its readings in order to give an approximately true indication of the total solids found in the diffusion juice of Kansas sorghum. For sorghum grown in New Jersey, which was the source of most of the juices examined here, the correction will be only about 7 per cent.

I am having constructed some saccharometers with scale to read as indicated by the above corrections.

The apparent purities of the sorghum juices will be considerably raised by this correction. Thus at Douglass the purity of the normal juice is raised from 59.63 per cent. to 65.31 per cent., and at Conway Springs from 66.70 to 72.76 per cent. The purity of the diffusion juices of the two localities is raised from 58.59 to 66.86 per cent. and 62.92 to 71.13 per cent., respectively.

SUMMARY.

It has been my duty during the past few years to report the facts concerning the sorghum industry as they were developed by the researches of the Department and of others. These facts have been of a varied nature; sometimes they have been favorable to the industry and sometimes unfavorable, but in all cases they have been fully set

forth and commented on in the light of the knowledge at hand. In these investigations I have been unmoved by the abuse of interested parties which I have received on account of my unwillingness to conceal the weak points of sorghum. It was thought when Bulletin No. 18 was issued that the experimental work on the part of the Department with sorghum was finished, and in that bulletin a summary was made of the investigations conducted in the United States during the past twenty-five years. In that bulletin I expressed the belief that with cane as rich as had been produced in Kansas on a large scale it was probable that a yield of from 80 to 90 pounds of sugar per ton of clean cane can be secured. The results of the past year confirm me in this opinion, and indicate that with wise management and careful control, and proper selection of locality, the sorghum-sugar industry may be financially successful. In previous pages I have endeavored to set forth carefully some of the things which must be considered in order to secure the above result; but it must be remembered that my individual opinion is simply based upon the study of the facts which have been set forth. These data are accessible to every one who cares to make a careful study of the subject, and therefore each one interested has every opportunity to form his own opinion concerning the matter. Since it is my business to investigate rather than to theorize I have contented myself chiefly with reporting facts rather than expounding theories.

ABSTRACT FROM REPORT OF H. A. HUGHES.

RIO GRANDE, N. J.

The whole season of this year has been devoted entirely to experimental work, with the object of securing additional light on crop-growing, manufacturing, and commercial problems.

The past season was the end of a series of crop-growing, covering a period of nine years, and fully confirmed the fact that the safe time for planting Orange cane, after allowing for variations of climate, had passed.

Analyses.

Description.	Sucrose.	Brix.	Purity.
	Per cent.	°	
Amber	7.35	13.70	53.60
Kansas Orange	8.47	14.21	59.60
Late Orange	6.74	12.01	53.80

The limit of crystallization can be marked at 55 per cent. purity. Crystals can be formed below this degree, but they are difficult to separate in the centrifugals.

The Late Orange was mostly below the crystallization point, and although crystals were attempted by the sugar-maker, in order to find out the limit at which graining takes place, and several pans were actually grained, the grains were so small that conclusions were reached adverse to the boiling for sugar of such material.

The following deductions are made from the analysis of more than 38,000 tons of cane, and cover a period of nine years. This table will be found convenient for reference, under the heading of season 1880 to 1888, inclusive. It must be borne in mind that these facts will only strictly apply to this climate and this soil; but until it can be proved that they will not apply elsewhere, it will serve as a guide, and should be interpreted by taking into consideration the fertilizers used, the variations of the seasons, and the nature of the plant.

SEASON 1880.

Ripening of the cane was traced with the polariscope, and when 14 per cent. of sugar was reached cutting began; and during the short time required to harvest it

no damage was received from winds or frosts. The juice was reduced to semi-sirup in an open evaporator, and three weeks later was shipped to Philadelphia and worked for sugar, marking firsts, seconds, and thirds. The cane was planted in hills 4 feet apart, and sufficient plant food used.

The impression made by this crop was that rich cane could easily be grown on poor land, and that with a little more fertilizing large crops could be made. It has since been found by long and costly experiment that all the conditions for Amber cane were most favorable excepting that a large tonnage could only have been secured by proportionately fertilizing.

SEASON 1881.

Farmers raised the entire crop. The acreage was not known. It was proved this year that with seed from the same lot some farmers grew cane 14 per cent. of sugar in the juice, while others grew it with only 6 per cent. Many conjectures were made, and the impression prevailed that some lands were suitable for cane and others unsuitable. It was, however, apparent that all who had the best reputations for farming raised the highest testing canes.

SEASON 1882.

Cane was grown by the company. Pacific guano high in nitrogen was used, and only Amber cane was planted. The Late Orange cane was grown only in sufficient quantity to supply seed for the next year. The nitrogen had the effect to keep the cane leaves green for a long time, and even after frosts the cane remained in good condition, and was on November 4 higher in sugar than on September 4. Since we have had less nitrogenous fertilizing and more of other plant food this variety had steadily fallen in test, and the period during which it retains its highest sugar content has been shortened. It is not safe to depend on this variety of cane for the whole season even if nitrogen is used largely with other plant food, because of its tendency to lodge and break with high winds.

SEASON 1883.

Yard composts and begasse were used in such small quantities that the nitrogen did not stand out prominently. The Amber had gone by its season before October 8, and had not the Late Orange been substituted this season for sugar-making would have ended on that day instead of November 14, when the crop was all in.

SEASON 1884.

Stable manure in large quantities, also a dressing of dissolved bone ash from South America, rich only in phosphoric acid, was used.

The phosphoric acid ripened the cane fully two weeks earlier than usual, and although the leaves were dry the Amber cane held its sugar content without loss, until worked up on October 11. The Late Orange was affected in the same manner, according to its season; and although apparently dried up too, still held its sugar.

Mill-juice tanks containing 6,000 gallons were quite common, testing 13 to 13½ per cent. of cane sugar from October 11 to October 29, after which time there was a gradual falling off, until November 11, when the tanks stood 12 per cent. and 77 purity; this ended this season, as the crop was worked up.

The small experimental plots conducted by the State experiment station have always showed that, by doubling the dose of phosphoric acid, the cane sugar falls off seriously; but as it is my intention to deal only with cane in immense masses as found at the sugar-house, I merely call attention to this fact.

This year produced nearly 400,000 pounds of merchantable sugar, and there was found, by adding the sugar in the molasses and the loss in the begasse as it came from the mill, that over 1,500,000 pounds of sugar were in the crop.

Molasses only was made from the begasse this season, diffusion being for the first time applied.

SEASON 1885.

No phosphates were used, and there was not enough compost to properly furnish nitrogen to the crop; still, the nitrogen was felt, and when the season commenced on September 2, the cane was so green we at one time thought it would be better to stop work.

When work was begun the Amber cane contained 5.04 per cent. of cane sugar and increased to 8.8 per cent. on September 29, when the variety was all brought in. The Late Orange cane contained 10 per cent. of sugar when first cut, and gradually raised to 12.57 per cent., slowly declining to 10 per cent. by November 11, the end of the season. This crop was planted practically at the same time as the crop of 1884, and harvested at the same time. Had a large quantity of nitrogenous fertilizing been used the sugar contents would have been much higher. Small quantities of nitrogen on lands deficient in organic matter will make poor crops. This was our experience again and again, and to secure immense crops high in sugar, potash should be combined with nitrogen.

SEASON 1886.

Small quantities of nitrogenous fertilizing and light dressings of muriate of potash were used. The crop suffered severely for lack of food. During the season, where plenty of nourishment had been supplied, the crop came to the standard. When this was not the case, the Amber seed remained in a milky state for a long time and soured as it stood in the field, after three days of abnormally hot weather, making the cane unfit for sugar-making. The Late Orange suffered from lack of nitrogenous fertilizing, and the sugar test rose and fell in proportion as this food and potash were present; but, being a longer feeder, it did not suffer throughout the season so much as the Amber.

The Kansas Orange was introduced this year, and being a stranger, the ground was properly selected and composts and potash applied in sufficient quantities, a 12 per cent. cane, with purities over 70°, being its record. The record of the Late Orange cane for the balance of the season is high and low test, according to the land, finally ending with the crop all harvested with a test of 9.45 per cent. This crop discouraged the sugar company notwithstanding the gains by diffusion, which process had been introduced in 1884. Local agriculturists pronounced the verdict that the lands being exhausted by continual cropping were ruined and unfit for crop of any kind. The plantation was then sown in clover; no fertilizing was done. The farmers laughed at the notion that land unable to grow large cane crop could be expected to grow grass; but it did, and the clover crop on these lands has been unprecedented and are the envy and wonder of local farmers, and judging the land from the farmers' own stand-point, it is to-day in better condition than ever before. The clover had found the missing nitrogen and furnished organic matter.

A lot of land on these farms grew poor cane for years, and in 1887, instead of planting it with clover, composts and potash were supplied and cane planted; by planting the ground with twice the number of hills to the acre, portions of the land approximated 28 tons of cane to the acre.

SEASON 1887.

The cane was planted from May 9 to June 3, and the late varieties failed to mature properly. A good dressing of begasse, yard compost, and potash was used. The crop was doubled by planting 3 feet by 24 inches; purity ran about 64° and tests were good. The Late Orange cane ripened sufficiently to retain its sugar in crystallizing quantities, through frost and ice, until December 5. Particulars of this season can be found in Bulletins No. 17 and 18 of the Agricultural Department, and in reports of the New Jersey Experiment Station. A small plot was fertilized with large quantities of nitrogenous manure and planted with Amber seed grown in 1886, from which no cane sugar could be made. The cane was tested on September 7, 1887, and was found to test 13.35 per cent. cane sugar; Brix, 17.21°; purity, 78; and it remained a long time after in fine condition. The same day milled chips from a field planted from the same lot of seed and fertilized with potash and phosphoric acid, polarized 8.88 per cent., and had a purity of 63.61.

SEASON 1888.

Only complete fertilizers were used on one field, and muriate of potash was spread on another field that was poor and had never been in cane. The hills were 3 feet by 24 inches.

Amber cane was planted on May 18 and Kansas Orange and Late Orange from May 19 to June 10. A cold, wet June followed, and the result was unripe cane. The crop was taken off between September 23 and November 1. The Amber cane was very poor in sugar. The Kansas Orange ran from 9.58° to 8.25°. The stand on one field of Orange (Kansas) was preserved intact from cut and wire worms by patches of volunteer canes where seed had been stacked previously, and some seed had been left on the ground. The worms gathered where plants were the thickest,

leaving the hills almost unmolested. When the ravages are feared, seed could be sprinkled down the center of the rows, and afterwards be destroyed by the cultivator without extra expense. They only destroy while the plants are very small and disappear with the return of dry, hot weather.

The Late Orange tested from 6.94 to 6.54 per cent. Scarcely any seed on this variety was ripe, and in a great many of the plumes seed was not formed, neither had the cane power to resist ice and frost. These facts prove conclusively that the safe time for planting Late Orange had been passed. It is possibly true this variety might have been very rich in sugar with a late fall and hot weather during June and September; but this risk is not a safe one, and as it positively can be avoided by earlier planting it should be done.

OBSERVATIONS.

The time for planting cane in this climate is, for Early Amber, not later than May 20; Kansas Orange, not later than May 10; Late Grange, not later than May 1. Ten days earlier can safely be risked.

Nitrogen prolongs the vitality in cane. Nitrogenous fertilizers combined with potash is the best combination for large crops and high-testing juice. Phosphoric acid hastens the ripening of the cane about two weeks, and too much phosphoric acid reduces the quantity of sugar in the juice.

Potash makes large and strong stalks. If canes are desired to be worked after frost and ice they must be supplied with ample food, be well grown, and of a late variety. If canes are not well advanced when frosts and ice strike them they will not be able to hold the cane sugar long. The earlier the variety the later it should be planted. If canes increase rapidly in cane sugar soon after frosts strike them they will soon be worthless for sugar-making. If they do not increase at all, or very little, they will remain good for a long time, providing the frost was severe, long enough to kill, or almost kill, the leaves. The Amber has less power to resist frost and ice than Kansas Orange, and the Kansas Orange less than the Late Orange.

The time which the sugar remains in high percentage in the cane is largely under the control of the cultivator. In all attempts to improve the seed by selection and increase the sugar and purity, the cultivation must be taken into consideration. High-testing seed will make poor-testing canes if plant food is not present in sufficient quantities or if the cultivation is neglected. Poor-testing seed will give high-testing canes if the seed is of a good variety, and ample food has been supplied, with good cultivation.

Canes can not be grown, rich in sugar, by starving them. Ground well supplied with plant food and badly cultivated will give very small canes, rich in sugar. That there are other peculiarities in other varieties is shown plainly in the case of the White African. Although planted late last spring, and the ground fertilized precisely like the Amber and Kansas Orange, it contained this year 12.30 per cent. cane sugar, purity 69°, on September 27, time the field was out.

The seed was given to the writer by Dr. Collier along with sixty-eight other varieties in 1883, all of which were planted, but for certain good reasons this cane was the only one selected from the lot. It has been grown since then each year, always giving high percentages of sugar. Some of its peculiarities are, viz, the unusual toughness of its stalk when overripe, and its great strength at all times.

It is hard, for some unexplained reason, to get a good stand. The seed is white, and local millers, with their crude appliances, have told me that they could get 30 pounds of flour from 1 bushel of seed, which, mixed with a small proportion of wheat flour, is preferred to buckwheat. The birds ravage the seed, and will select it from a hill planted with mixed Orange and Amber canes, leaving the other varieties unmolested. In order to be protected from these depredators and secure the seed, plots of sufficient size must be raised and calculations made for this loss. It has been found true here that they will not take quite all the seed from one acre in a season, consequently plots of 5 or 10 acres are comparatively protected.

The purity of the canes of this variety has been noticed as high as 77.92.

The cane has not been properly studied and the birds have taken nearly all the good seed from the acre raised this season.

MANUFACTURING.

I will confine myself in my report to methods adopted for the first time this year.

SAWDUST FILTERS.

It has always been found that filtration of the juice through some medium that would remove the particles of matter mechanically suspended was necessary. For two years filter presses were used. It was found if the juice were alkaline it would filter much better, but gave highly colored products,

Last year Dr. Wiley advised the use of sand. This gave good results for a time, but gradually ran slow and failed to give satisfaction. The size of the filters in proportion to the juice worked was very large and it soured easily.

EVAPORATOR.

In accordance with your instructions, I constructed an open evaporator to be run by crude oil (petroleum). Parallel brick walls, 13 inches thick, 34 feet long, and 24 inches high, were constructed. At one end was an iron stack, and at the opposite end were the burners. Upon the walls was placed an open evaporator of sheet-iron 2 feet high, 30 feet long, and 4 feet broad, divided by partitions 8 inches apart, 6 inches high, and 45 inches long. The juice entered the pan over the burners, discharged at the opposite end, traversing a distance of about 164 feet in twelve minutes.

The skimmings remained at the end over the burners and were easily removed. As this was the first time to my knowledge that crude oil had been applied to sugar work, I was able to collect little data to guide me. After examining personally the burners in use for steam-boilers, I finally adopted one belonging to H. W. Whiting, of Philadelphia. He advised me to place three burners at the end and insert in the brick-work at intervals of 1 foot inch pipes to extend completely through the walls and flues, and to be perforated with holes one-quarter of an inch in diameter and 3 inches apart. The intention was that air should pass through the perforated holes into the flue, and thus aid combustion.

The burners were made from 2-inch pipes with a T fitting open at the bottom to supply air; on the Bunsen burner principle, the oil passed through a quarter-inch pipe, through a cock into a 1½-inch coil 1¼ inch in diameter, so placed as to receive a large portion of the heat from the burners; there is also a quarter-inch steam-pipe leading into the end of the pipe so that the oil and steam can be mixed as it passes into the hot coil or superheater, as it is named. When the oil is converted into gas from the superheater it passes into the Bunsen burner and is forced through it by another steam jet and burned from the opening.

In our first experiment Bradford crude oil was used, and in our final experiments black residuum of the refineries, which I have been informed is the product left behind after the light oils have been distilled off.

In practice we could find very little difference in the heating of the two oils. Lima oil could not be had in quantity less than six thousand gallons, consequently was not used.

It was found in starting the burners that a stack 10 inches in diameter was too small, the effect in practice being to cause explosion of gas.

A stack of 24 inches diameter was substituted; this stopped all explosions but wasted the heat. Dampers made of fire-clay were then used, and it was found that after the superheater was hot enough to generate gas freely the dampers could be safely closed. Care had been taken in constructing the dampers to arrange them so that there was left on the sides a space equal to about 12 inches square, after they were in. A further improvement in the heating was made by filling in next to the stack with dirt. This bank of earth was then extended back into the flue for about its length and paved on the top with bricks. There was left a space of about 9 inches between the pavement and the bottom of the evaporator, and in filling in the flue the combustion pipes were covered up for the length of the embankment. The combustion pipes directly in front of the flame were soon burnt out. No detrimental effects being perceptible from the loss of this air, it is safe to conclude that they were of no value.

The owner of the burners thought we would evaporate at least 15 pounds of water for each pound of oil burned and hoped we would reach 18 or 20 pounds. The record of the best day's work shows $7\frac{8}{10}$ pounds. It is but just to say that the evaporator was entirely too large for the work it had to do, and the walls had time to cool before starting each day. Now it is found that if the walls and surrounding mediums are much lower than the temperature of the gaseous product of the Bunsen burners, condensation takes place and the oil is fried, as it is called, instead of being generated into gas, which is wasteful in the extreme. One-third of all the oil burned was generally used in starting the burners each day. Another source of loss long evaded our researches. It was caused by using cocks to feed oil to the superheater. A common quarter-inch globe valve was substituted for the cock, which brought the burners under full control and enabled us to burn only one-quarter as much oil. I make the suggestion that pipes for supplying oil to the superheater should be less than one-quarter inch; that globe valves less than one-quarter inch be used, and that threads that regulate these valves be made as fine as possible so that they may have the most delicate adjustment. I can not tell the saving of all these apparent improvements because I had not time to get the record properly.

Taking the record as it is and counting the price of oil at $1.25 per barrel, about one-half of the water was removed from the diffusion juice of each ton of field cane for 31 cents per ton.

AUXILIARY HOUSES.

The auxiliary houses have been kept steadily in view during the season's work, and the fact has been remembered that the industry will spread and succeed at a much quicker rate if the capital necessary to conduct the business is kept as low as possible consistent with good management. The cost of building sugar-houses is reduced to a minimum and labor saved. There is no good reason to expect to make money out of the sorghum business unless conducted on sound business principles. The knowledge of the business is now advanced to such a point that there is nothing to prevent accurate calculations being made. The cost of the machinery, the work it can do, the labor required to run it, the cost of the cane, the yield and quality of the product can now all be closely estimated.

Sugar-houses built without definite ideas of the work to be done or machinery added piece by piece, without plans or contracts, and such machinery as clarifiers, as filter presses and bone-black drones added, with the expectation of only making white granulated sugar directly from the juice, will be certain to bring financial failure and disappointment to its projectors, unless the capital is heavy enough to stand the strain, or the parties are willing to make experimental work of their plants and pay the price for doing it. Notwithstanding the closeness with which all these calculations can now be made, the following should be remembered. I have never known a sugar-house of any kind to be made so complete and be in such fine running order that it could be depended on to make a commercial success the first season. Either its water arrangements will fall short of expectations, or the boilers fail to be large enough, or strikes and delays will detain the mechinery, or castings will be broken in shipping, or some minor points will be badly proportioned or too weak, foundations will prove not sufficiently secure, shafts will be found out of line, etc. All this will occur, not from any bad management, but because the nature of the work is such that the factory can only perform its task satisfactorily after being broken in on cane. The cane alone can give the necessary adjustment. Erroneous and disappointing calculations have been made by celebrated sugar engineers in making calculations for sorghum, by using well-known standard rules for the evaporation of water as a basis for calculation; and repeatedly has machinery proved suitable for Southern cane failed when applied to this work. The moral of all this is, that in constructing new works there should be only enough cane raised the first season to break in and test the sugar-house thoroughly in every part, in order that when the machinery is called upon the succeeding season, it would fulfill the work it had been calculated to do without delay or hindrance.

The expense of doing all this should be allowed for in the capital account.

In some sorghum houses, calculated to work 100 tons of cane a day, will be found strike vacuum pans of such large size that the cost of erecting them and the pumps necessary for their use, the large pipe fittings and other paraphernalia, will cost as much alone as would suffice to build an economical sugar-house of good size.

Experience had taught us that there is a limit to the size of sugar-houses, and that it costs very little more to man a 40-ton house than a 20-ton, and the proportionate cost of constructing is greatly in favor of the 40-ton plant. For sugar-houses of larger size I can not yet give accurate data with safety.

ABSTRACT OF REPORT OF PROF. W. C. STUBBS.

KENNER, LA.

Several varieties of sorghum were tried. These were planted on April 18, thinned to a stand, and cultivated in its order with the corn crop. Here flat cultivation was exclusively practiced during the season, while at the other two stations high ridges were required for drainage.

These plantings were made with a view of testing, by mill and laboratory experiments, the adaptability of sorghum as a sugar crop to Louisiana. If sugar can be made profitably from sorghum anywhere in the United States it should be done in Louisiana. Chemical analyses show a larger percentage of sugar and a smaller quantity of glucose in sorghum grown in Louisiana than anywhere else in this country. At least the published analyses now at hand verify this assertion. Again, could our sugar-planters be persuaded that sorghum could be made to yield a profitable quantity of sugar, say, even 1,000 pounds per acre, they would soon adopt it as an adjunct to the cane crop.

Again, there are vast tracts of rich alluvial lands in the middle and northern portions of the State which are too far north for cane, and which will grow excellent crops of sorghum. These lands are now in cotton, but could it be demonstrated that they could grow sorghum profitably, central factories would spring up in every direction and this crop would supplant cotton in part if not entirely.

With these possibilities in view, the director has persistently planted sorghum for three years upon the sugar experiment station and attempted every year to make successfully sugar from it by the milling process. Chemical analyses have shown that our juices were rich in sucrose and low in glucose, but our sugar-house experiments have failed to extract it successfully. We have made the *masse cuite* full of grains, but our centrifugals failed to purge. All this was due to the starch present in the juice (extracted by pressure with the mill), which, during the subsequent process of concentration, was concentrated into dextrine, and this substance, our *bête noir*, prevented the elimination of the sugar. Our past experiences have demonstrated the inapplicability of the crushing mill to sorghum. They have also shown that high temperatures must be avoided. Therefore new methods of extracting the juice and processes of cooking in vacuo must be resorted to before we can successfully extract sugar from sorghum.

From our past experience with sorghum it was inferred that our crop planted on the 16th of April would not be ready for the sugar-house before the 1st of September. Accordingly we contracted with Messrs. Edwards & Haubtman to deliver the machinery by the 15th of August, thus giving us fifteen days (ample time) for its erection and preparation for work. Messrs. Edwards & Haubtman failed to deliver until the 23d instant, which failure, in connection with the unprecedented storm of the 19th instant, which prostrated completely our sorghum, proved most disastrous to our successful manufacture of sugar.

In 1886 sorghum planted April 5 was harvested 13th September. In 1887 sorghum planted April 21 was worked up September 23. Both years they were worked at full maturity, excepting the Early Amber and Chinese, which were ripe in July of each year.

It was fair therefore to calculate that, without any natural intervention, the sorghum this year would not be ready for the sugar-house before the middle of September; and had not the storm prevailed the date of delivery of Messrs. Edwards & Haubtman would have still afforded us ample time to have completed erection before the maturity of the crop. Either alone would not have proven disastrous; both together were fatal.

STARCH IN SORGHUM.

With green canes just heading no indications of starch are given by iodine. If there were any blue it was completely obscured by the intensely brown coloration. This brown coloration indicated dextrin and other forms of soluble starch.

With well-matured canes iodine gives an intensely blue color towards the top, decreasing in intensity towards the butt. Canes occupying an intermediate condition between these extremes, or in that stage of growth when maturity begins to appear as indicated by the presence of sucrose in the lower part of the stalk, starch will be found in the butt but not in the top.

The above conclusions of Mr. Hutchinson have been fully confirmed by subsequent experiments; and it is not unusual in our laboratory now to prognosticate the amount of sucrose in a cane by the presence of starch, so intimately are they associated. Both sucrose and starch seem to be formed simultaneously—the former from glucose and perhaps other bodies, and the latter from dextrine and other soluble forms.

Glucose occurs in largest quantities when the polariscope gives no indication of sucrose by single polarization. In a sample of green cane, in which there was no starch and by single polarization no sucrose, but by double polarization 1.53 per cent., as high as 7 per cent. of glucose was found. As the cane from which the above sample was selected matured, repeated analysis made at short intervals showed that the glucose decreased until at maturity it reached as low as 0.8 per cent.

EXPERIMENTS IN DIFFUSION.

Without entering into the full details of daily work, the following taken from our large amount of records will suffice to illustrate fully the work performed.

Considering the very low character of the sorghum worked the results obtained are quite promising.

Wednesday, September 12.—Having repaired the defects, work was begun at 9.30 o'clock and continued until nineteen cells had been filled. Everything worked admirably, except the heaters, which were not under control, and hence varying temperatures used in diffusing. Weather very warm and much suffering experienced by everybody at work, particularly by the men at the diffusors and clarifier.

It was utterly impossible, from the varying amounts of sucrose in the canes used,

to get anything like uniform results, either on the juices or chips. There were drawn four clarifiers of about 500 gallons each. The last two were very dilute owing to the excess of water used in washing the chips after cells were filled. This juice was heated with lime and brought to neutrality; heated and blanket, which was quite insignificant, removed. It was then settled and clear juice run into the double effect and concentrated.

There was a large quantity of settlings and some scums, which were weighed and analyzed and thrown away to avoid interfering with the well-clarified sirup. The following are weights obtained:

	Pounds.
Sirup	1,562
Settlings and scums	1,070
Sugar	49
Molasses	752

The following are the notes of diffusion: Every effort was made to hold the temperature at 200° Fahr., but until the battery had been used in one entire round this is almost impossible to do, since sending in quickly water heated to 200° Fahr. into cold iron cells filled with cold chips, the loss of heat by radiation and convection is very great. Six minutes were allowed for the diffusion of each cell after the hot water was turned on. Every effort to grain in the vacuum pan proved abortive, as the following notes of Mr. Baldwin, who has charge of the pan and was assisted by Mr. Barthelemy, will show:

"Part of juice concentrated in double effect on first watch; remainder on second watch, when the juice got very hot, 180 degrees, and was emptied in cars to cool; finished concentrating on morning of 13th, at a temperature of 155 to 160 degrees Fahr. Juice dark-colored and some feculent matter present. After mixing sirups started vacuum-strike pan at 2 p. m. on 13th; temperature 138 to 140 degrees Fahr.; very thick; nothing but candy would form in the pan. Allowed to stand half an hour until candy dissolved, but no grain. Stood again one hour; at 7 p. m. still no grain. Cooked very thick and remained in pan until 2 p. m. next day, when it was all boiled to string sugar and put in the hot-room. Injured some by being cooked to candy.

"In the hot-room it at once began to grain, until the wagon was quite solid with small grains of sugar.

"It was centrifugaled and gave the following results:

Sugar	pounds..	49
Molasses	do. ..	752

Recapitulation.

Cane contained	pounds sucrose..	349.75
Sirup contained	do......	273.22
Scums contained	do......	20.33
Chips contained	do......	56.20
Sugar contained	do......	44.58
Molasses contained	do......	228.61
Sugar obtained	pounds per ton sorghum..	15.5
Molasses obtained	do......	237.1

After the analyses of the mill juices were known little or no hope was entertained of successful sugar results. Indeed, it is wonderful, with such juices and after such treatment, that any sugar should be obtained.

September 17.—It has often been published that neither sorghum nor its juices will stand transportation or delay in working them up after being cut. That such is not the case with us is abundantly proven by the following and many other experiments during this season. On September 16, Mr. Barrow, assistant at the State experiment station, was sent to Baton Rouge to harvest and ship a car-load of sorghum from that station to this. By 9 a. m. on the morning of the 16th, he had cut and loaded a closed car with Early Orange sorghum. This sorghum was quite wet from dew, and had its leaves and tops still on, conditions making fermentation quite feasible to almost any crop. It was delivered at Kenner by Mississippi Valley Railroad at 7 p. m. of same day. It was unloaded and delivered at sugar-house at 12 m. of the 17th, and worked up as delivered. This cane had been badly blown down by the storm of the 19th, and was filled with suckers several feet long, now in full heads. It was quite low in sugar, as the following analysis of selected stalks made on September 11 showed:

	Per cent.
Total solids	11.9
Sucrose	7.8
Glucose	4.52

Began diffusion at 9 a. m. Filled twenty-three cells with chips and drew off thirty-one cells of juice. Finished in early evening, after two slight detentions. Cells diffused sixteen minutes each, except three times, when interrupted. The temperature varied from 150° to 200° Fahr. The juice was boiled to a sirup in double effect and made into string sugar in the vacuum pan. Boiled all night, finishing the next day. The string sugar was run into the hot-room, where it was grained into almost a solid mass. The following are the amounts used:

		Pounds.
Weight of canes		13,266
Less weight of—		
Tops	2,445	
Leaves	1,785	
Trash in yard	1,558	
Chips not used	82	
		5,876
Clean cane used		7,390

The juices from this were concentrated into a sirup, giving 1,491 pounds; scums thrown away, 313 pounds; juice made into molasses, 259 pounds.

The following are the laboratory results:

	Pounds.
Sugar obtained	115
Molasses obtained	672
Sugar per ton of sorghum	31.4
Molasses per ton of sorghum	181.8

Recapitulation.

Cane contained (calculated)	pounds sucrose	435
Sirup made into sugar contained	do	328
Sirup made into molasses contained	do	57
Scums contained	do	7
Chips contained	do	32
Fiber in cane	per cent	15.5

[Variety: Early Orange.]

	Total solids.	Sucrose.	Glucose.	Glucose to sucrose.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Mill juices	11.4	7.0	3.33	48
Do	11.3	7.0	3.58	51
Do	11.7	6.9	3.30	48
Diffusion juices		3.2	1.79	56
Do		3.95	2.00	51
Do		3.00	1.92	64
Do		3.90	2.17	55
Do		3.90	2.32	59
Do		4.10	2.00	48
Do		3.50	1.72	49
Do		3.70	1.46	39
Do		4.10	1.73	42
Do		3.50	1.50	48
Do		3.60	1.66	46
Do		4.20	1.62	38
Do		3.90	1.70	44
Do		3.30	1.60	48
Diffusion chips		.3	.14	47
Do		.3	.18	60
Do		.25	.16	64
Do		.35	.149	43
Do		.25	.14	56
Do		.15	.13	90
Do		.15	.10	40
Clarified juices		3.6	1.85	51
Do		3.9	1.60	41
Do		3.1	1.57	51
Do		1.8	.99	55
Do		1.3	.56	43
Do		1.1	.54	49
Sirup		22	11	50
Scums		4.2	2.22	53
Sugar		92.1	2.94	
Molasses		34	22.72	

Here, as before, the dilution was great owing to the water used in washing the chips after cells were filled. This cane had nearly a constant composition, and from glucose ratio there has been little or no inversion either in cells or in concentration of sirup. In fact, when water at 200° Fahr. is sent into cells and maintained there for six minutes at this temperature, little or no inversion took place, notwithstanding the weather-gauge showed this day a maximum temperature of 83° Fahr.

September 20.—The following canes were selected for this run: Link's Hybrid, White India, White Mammoth, and the second planting of Early Amber. The suckers, of which there were many, were removed by hand. Filled nine cells. Everything worked well.

		Pounds.
Weight of cane used		5,078
Less weight of—		
Tops .... pounds..	812	
Trash .... do....	653	
Suckers .... do....	208	
Chips not used .... do....	74	
		1,747
Clean cane used		3,331

Juice neutralized with lime, blanket removed, settled, concentrated in double effect and grained in vacuum pan; then emptied into car and run into hot-room, where it solidified into crystals of sugar of small size.

	Pounds.
Weight of sirup	695
Weight of scums, etc	150
Weight of sugar	40
Weight of molasses	235
Sugar per ton	24
Molasses per ton	141

The following are laboratory results:

	Total solids.	Sucrose.	Glucose.	Glucose to sucrose.	Variety.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	
Mill juices	10.6	6.7	1.48	22	Link's Hybrid.
Do	14.1	10.0	1.25	12½	White India.
Do	10.5	6.9	2.14	22	White Mammoth.
Do	10.7	6.5	1.92	29	White Amber (Nebraska).
Do	10.4	5.4	3.12	57	White Amber.
Diffusion juices	4.8	3.05	1.13	37	
Do	6.0	3.50	1.51	43	
Do	6.0	3.70	1.51	41	
Do	5.2	3.20	1.57	49	
Do	5.6	3.25	1.61	49	
Diffusion chips	....	.20	.16	....	
Do	....	.30	.14	....	
Do	....	.20	.13	....	
Do	....	.10	.12	....	
Do	....	.10	.12	....	
Clarified juices	5.9	3.5	1.39	39	
Do	2.1	1.4	.51	38	
Sirups	32.94	17.5	7.04	40	
Scums	....	1.7	.73	41	
Sugar	....	92.2	2.93	....	
Molasses	....	34	20	....	

RECAPITULATION.

Sucrose in—	
Sirup .... pounds..	121.62
Scums .... do....	2.55
Chips .... do....	16.56
Sugar made .... do....	36.88
Molasses made .... do....	79.90
Fiber in cane .... per cent..	15.04

CONCLUSIONS.

While the present season was in Louisiana a most disastrous one for making sugar from sorghum, yet the successful application of diffusion in the extraction of the juice from both sorghum and sugar cane has been abundantly proven.

From sorghums of fair quality, such as were raised on this station in 1886 and 1887, it is certain that a large quantity of sugar could be obtained. From Early Orange this year, with only 9 per cent. sucrose and 3.33 per cent. glucose (glucose ratio nearly 50) 31.4 pounds sugar were obtained to ton of sorghum. This same variety showed in 1886 a sugar content of 13 per cent. with a low glucose ratio, and in 1887, a less favorable year, sugar content of 10.5 per cent. and only 13 as the glucose ratio. Could such cane have been diffused this year, a yield of fully 100 to 125 pounds per ton might with reason have been expected.

However, this station will repeat again the experiments next year, with more promise of success.

REPORT OF HUBERT EDSON.

DOUGLASS, KANS.

After one or two trials to test the machinery of the house, the regular manufacturing season at Douglass commenced September 14, and continued with what regularity was possible up to October 25.

There is no doubt but that the Early Amber was ready for work by the middle of August, and possibly earlier. When I arrived in Douglass, August 26, I found several fields that had passed maturity. This cane, however, contrary to experience elsewhere, did not deteriorate in any marked degree till some time after reaching its maximum sucrose. When the house was closed we still had Amber coming in in large quantities and containing sucrose enough to warrant working it.

Besides the Amber, the two other varieties chiefly grown were the Orange and a cane identified by Mr. Denton, of Sterling, Kans., as the Chinese.

The Amber and Chinese contained highest sucrose and lowest glucose, with the advantage slightly in favor of the Chinese. The Orange did not do as well as was expected, but it was planted so late in the season that it did not have time to mature.

The exceedingly variable nature of the cane brought in was a source of constant annoyance, nor would the appearance of the stalks be any criterion of the quality of the juice. One field of 30 acres which had been ordered hauled in before any test had been made of it was found, on the arrival of the first load, to contain but 4.50 per cent. sucrose, with almost as much glucose. This cane was, judging by its appearance, as good as any worked during the season, but repeated tests of samples taken from different parts of the field failed to show in a single instance enough sucrose to warrant working for sugar. Numerous instances of this same thing were found throughout the season and the cane needed the closest watching.

One thing it would be well to impress upon the sorghum-grower, and that is, the necessity of growing small or medium-sized canes. From numerous trials of comparative samples, the highest sucrose and lowest glucose were always found in the smaller canes. Fields, also, where the small and slender canes predominated were always of superior quality. The best cane analyzed at Douglass was a sample from a field sowed for fodder, in which the seed had been scattered broadcast on the land, and as a consequence grew very small. Of course I do not mean to advocate the sowing of sorghum seed to grow a product for the sugar-house, as then too large an amount of sheath and leaves would be obtained, but it is necessary to avoid large, rank stalks, as the desire is to obtain a high content of sucrose.

THE SUGAR-HOUSE.

The house was designed to work 100 tons of field cane daily. The Hughes cutter and shredder were used. The trap-door just before the cutter through which it was intended to pass the seed heads failed to work satisfactorily. This was due in part at least to the heavy feed which it was necessary to keep on the narrow carriers in order to supply the battery with chips. The shredder when properly adjusted did excellent work, tearing the chips into a pulp if required.

The main feature of the house was the diffusion battery. This is known as the Hughes system of diffusion, and is described in Bulletin 17, Chemical Division, Department of Agriculture. The one at Douglass differed slightly, however, from the one described there. The main battery contained ten cells, with the baskets for holding chips used in his process, and in addition to these an outside cell was placed so that the arm from the large crane could reach the basket while immersed in it.

An extra crane was necessary to raise and lower the baskets in this cell, as it had to be worked without connection with the main battery.

The object of the cell was to give a dense diffusion juice, and thus save evaporation. As the battery progressed, the heaviest juice from two cells was drawn into the outside cell, and there received two baskets of fresh chips before being dis-

charged. This, as far as I was able to see, did not attain the object claimed for it, as no fresh chips ever reached the main battery, and consequently the juices were more dilute and needed the addition of two baskets of fresh chips to bring them to a normal diffusion juice. It is certain at least that the extra steam-power required to run the outside cell would a great deal more than suffice to evaporate any less dense juice that might be obtained.

Before passing to the work done by the battery as a whole, it is but just to say that there were mechanical defects in the construction which, if they could have been remedied this season, would have materially assisted the quality of the work. The bottom of the baskets, instead of being single and swinging to one side, were doubled and hinged to a cross-bar extending from one side of the basket to the other. As a consequence of this arrangement the emptying of the exhausted chips was a very difficult matter. But, on the other hand, a basket constructed strong enough to permit a single bottom would be altogether to heavy to use where so much of the work is done by hand.

The average sucrose of the fresh chips for the season was 9.88; for the exhausted chips, 1.72. The extraction of sucrose, therefore, was $9.88-1.72=8.16\div 9.88=82.59$ per cent. This extraction was accompanied by a dilution of 52.45 per cent., 16.89 (Brix of fresh chips)—8.03 (Brix of diffusion juice); $8.86\div 16.89=52.45$ per cent. With a dilution of this sort in a closed battery practically all the sugar would be exhausted instead of 1.72 per cent. left in by the Hughes process.

It was noticed that a regular ratio existed between the exhaustion and the dilution. As the dilution was increased the extraction became better, and *vice versa*.

Besides the amount of sugar left in the chips there was an unknown waste of immense quantities of juice from the drippings of the baskets in transferring them from the eleventh cell to the cells of the main battery. This loss it was impossible to gauge, but to any one who saw it it was evident that no inconsiderable amount was lost.

Nothing which we could think of to make the battery a success was left undone. For part of the time I shifted all of the laboratory work to my associate, Mr. Fuelling, and took charge of the battery. This I was prepared to do from a previous year's work with the inventor of the system, with whose plan of running the battery I was consequently familiar. Although the quality of the work was improved after the change I instituted, it was so far from being good diffusion that nothing was left to do but to condemn the apparatus.

THE DIFFUSION JUICE.

The juice as it came from the cells was full of finely divided fiber which had come through the perforations of the baskets, and was also of such a dirty-black color that it was impossible to clarify it.

Sulphites of lime were used for awhile, as were also superphosphates, but both were so full of sulphuric acid and accomplished so little that they were discontinued.

The juice probably acquired some of this color from its acids attacking the iron vessels in which it was kept so much of the time, but the main cause was the passage of large quantities of seeds through the diffusion battery along with the fresh chips. As was mentioned before, the cutter was too narrow for the capacity of the house, and a very heavy feed was kept on the carrier, preventing the seed heads dropping down through the trap-door designed for that purpose.

To illustrate that these seeds were the cause of the discoloration, Mr. Fuelling diffused two beakers full of chips, the one of them containing a few seeds and the other none.

The one with the seed gave the black color characteristic of the diffusion juice from the house, while the other gave a perfectly limpid liquor. I endeavored to have the superintendent of the house make a run, cutting the tops off in the field, but he failed to do so.

DISPOSITION OF EXHAUSTED CHIPS.

During the first part of the season a long carrier was used to convey the chips to the yard. It was intended to extend this as the yard filled, but the chains broke so often that this plan was given up and the chips taken off in carts.

The centrifugals did very poor work throughout the season, but so little sugar was extracted by the battery that it was not considered necessary to get new ones.

SUMMARY OF WORK.

During the season 2,167 tons of cane were worked.

Allowing 25 per cent. off for tops and leaves, this would amount to 1,623 tons of cleaned cane; 45,000 pounds of 94.45 polarization were obtained, or 26.2 pounds per ton of clean cane.

Eliminating the loss in the centrifugals, which would have been remedied if enough sugar had been obtained to justify it, the great loss in working the house was in the battery.

Certainly with two years such work as this apparatus has done there will be no more danger of its being used again in a sugar-house.

ABSTRACT OF REPORT OF E. W. DEMING.

CONWAY SPRINGS, KANS.

The experiments were conducted in connection with the work of the Conway Springs Sugar Company.

This company was incorporated April 10, 1888, under the laws of the State of Kansas, with an authorized capital of $100,000. Its officers are: G. W. Fahs, president; E. E. Baird, vice-president; G. B. Armstrong, treasurer; E. W. Deming, secretary and manager.

The factory was equipped with two tubular boilers of 150 horse-power each; two 30 horse-power high-speed engines; 3 hanging Hepworth centrifugals, with mixer; one 7-foot vacuum (dry) pan from R. Deeley & Co., New York. Hot-room, with fifty sugar wagons. Lillie double effect from George M. Newhall & Bro., Philadelphia. Diffusion battery from Shickle, Harrison & Howard Iron Company, Saint Louis: three cutters, with necessary clarifiers, skimming pans, and storage tanks. One dynamo of 100-lamp capacity, incandescent, provided lights for the building. Two sets rolls and a fire dryer for crushing and drying exhausted chips and one small open evaporator.

The diffusion battery consists of sixteen cells each 8 feet long and 35 inches in diameter, wrought-iron shell with similar castings, doors, and counter-weights at each end, provided with solid-rubber gaskets that gave satisfaction under a 30-pound per inch pressure. One heater for each cell, made of 6-inch wrought pipe containing 11 one-inch brass tubes 5 feet long; the connecting and circulating pipes were of 2½-inch wrought iron. The battery was placed in two lines of seven cells each, with one across each end, and supported on wooden posts, beams, and cross-beams 8 feet from the ground; each cell would hold 1,400 pounds of chips. The cost of this battery with pipe and fittings was $5,500; its work was in every way satisfactory. The exhausted chips were discharged into a chute of sloping sides, directing them into a drag of peculiar construction, delivering them into an elevated chute from whence a cart removed them. This apparatus worked well.

The double effects are each 4 feet in diameter and 18 feet long, placed on end; each has 70 three-inch brass tubes 8 feet long placed vertically; ends of tubes properly secured in plates, steam being admitted to the chamber about the tubes. Pumps draw the liquor from bottoms of pans discharging at the top, passing through perforated screens to the upper plate, from which it overflows a thin film of juice down the inside of all tubes alike; the evaporation occurs in the tubes: a vacuum is maintained throughout the tubes and circulating pipes. The vapor was removed at lower end of tubes, with suitable circulating pumps and a slight change in the tops to facilitate cleaning. They will not only have large capacity but unusual merit for handling sorghum juices. These pans, by reason of mechanical defects not difficult to overcome and the rapid formation of scale upon the heating surface extremely difficult to remove, caused some considerable delay to the work.

The first or second cutter, Hughes style, consisting of two heavy balance-wheels 36 inches in diameter placed 32 inches apart on a 3-inch shaft, two knives placed horizontally, connected the face of the balance-wheels. The dead-knife was placed 8 inches below center of the shaft, thereby making a bevel cut on the cane: space between end of drag and dead-knife 23 inches; this permitted the seed to readily escape the knives by falling into a drag.

Power was transmitted by a belt, the cutters making 200 revolutions per minute, cutting into 1-inch sections a bed of cane 30 inches wide and 6 inches deep. This cutter proved deficient in both strength and capacity. One-third of the delays and losses attending the work are traced to this source. Below the cutter was a single fan 20 inches in diameter and 30 inches long, having a motion of 600 revolutions per minute. Its work was especially fine.

The two shredders were each 20 inches long and 8 inches in diameter, provided with four knives held in place by a peculiar arrangement at the ends, leaving the face of cylinder free of openings; motion, 1,200 revolutions per minute; doing satisfactory work.

Three clarifiers of No. 10 iron, round, 5 feet in diameter and 30 inches deep, with cone-shaped bottoms. Two-inch copper coils were used. They lacked scum pockets; otherwise their work was satisfactory.

The cane shed consisted of two floors, each 10 feet wide and 150 feet long, separated one above the other by a space of 4 feet. As a means of storing cane this apparatus worked well.

An open pan, iron, of two channels, each 12 inches wide and 12 inches deep and 20 feet long, filled with three-quarter-inch copper coil, was at first used with steam as a skimming pan to aid clarification.

Later steam was dispensed with and the pan operated as a continuous-flow settling tank, giving better satisfaction and suggesting a possible manner of constructing a rapid system of continuous-flow settling tanks.

The cane is received from the farmer upon specially constructed racks. The wagon is driven on a turn-table by which it was squared about, then backed a few feet against an ordinary wagon scales on which was a raised platform 3 feet high; an iron hook was secured in the two ropes placed around the load by the farmer; a friction clutch at the opposite end of the cane shed, nearly 200 feet distant, drew the load over the rear end to the scales. Here it was weighed net, and the farmer's ropes removed. An endless sling was then thrown over the cane, the same power taking it into one of the floors comprising the cane shed, where it was left for night run or taken directly through to a small downward incline where two men pulled it apart, feeding to three chains with attachments that carried it 1 foot above a cross-drag leading to the cutters. The feed was regulated by stopping and starting this chain. This drag leading to first cutter has a motion of 40 feet per minute, carrying the cane in bundles a few inches of space between the tops of one bundle and the tops of the next; this permitted seed to drop freely. Seed was hauled directly to the field and left in small piles; that required for sugar work next season is carefully selected by hand, tied up into bundles of eighteen tufts, two bundles then tied together, and so hung up in a dry place. The rest is stacked, allowed to pass through a sweat, and thrashed in February. It is sold in large quantities at good prices to ranchmen, who sow it for fodder for stock. The inch sections of cane as they are cut fall into a strong blast of air direcly underneath, by which the leaves and the sheaths are removed. By means of a link-belt drag the cleaned sections are conveyed into the main building to an elevator, taking them above the roof, where they are discharged into the hopper of the shredder and reduced to a pulp, which falls into a carrier passing over the diffusion battery. Openings in bottom of this carrier permit the cane chips to be spouted to cells on either side.

Although the semi-sirup contained a purity often above 70, it was difficult and generally impossible to start a grain in the pan; a strike thus boiled to grain produced exceedingly fine grain difficult to purge and invariably dark in color, no better than a number of early strikes boiled to string.

These fine, gummy, dark sugars dissolved in clarified juices were used to start the grain ; an amount equal in weight to one-fifth that of each strike produced a fine sugar of medium-size grain remarkable for its uniformity of grain, color, and purity. All sugars were taken to the mixer and passed through the centrifugals as speedily as possible to remove them from contact with the black molasses.

The entire water supply was obtained from a bed of gypsum 65 feet from the surface, and was positively unfit for use in either the boilers or the diffusion battery. The injurious effects of this water was observed early, Dr. Wiley being the first to suspect the true cause. By the use of this water for diffusion there is a loss (estimated) of 22½ pounds of sugar from each ton of cane worked, or 35 per cent. It ruined the molasses, and to this gypsum is attributed, directly or indirectly, nearly two-thirds of the annoying and expensive delays and losses incident to the present season's work.

Canes of unusual richness were worked, the battery secured a good extraction, the entire evaporation occurred in vacuum with but slight inversion of sugar; but large yields of sugar did not follow.

The analyses of molasses from the sugars explains much, many of them showing the relative sugars four and even four and one-half to one, yet so engulfed with a mass of gums, black and bitter, as to render impracticable any attempt to secure second sugars.

In my opinion the estimated loss of sugar due to the use of this water should be doubled. I would respectfully ask critically inclined persons to keep these facts in mind when reviewing the accompanying tables, which contain notwithstanding some interesting and reliable information.

The farmer looks upon this industry as one created for his special benefit, and when considered from his stand-point, as judged by its agriculture, can see only magnificent successes for all sugar work. An average crop of cane as grown in this section at $2 per ton equals in value the land upon which it is grown.

No crops are grown with more certainty ; others, corn especially, in most localities of this section are not sure every season. One farmer growing 30 acres re-

ports an average of 13½ tons per acre. Some small pieces produced more, the average being 10½ tons per acre. Ten thousand acres at $2 per ton could easily be contracted for delivery next season. The farmers are not slow to see the advantages offered in growing cane at these prices.

The soil of this section can be called neither clay nor sand, being light, loose, not sticky, light in color, contains little organic matter, and produces only a medium-sized stalk of corn or cane.

But one trial run was made, worked by itself; 43 tons of cleaned cane, from which was obtained 3,850 pounds of sugar of 98 per cent. purity, and 1,000 gallons of molasses, being 90 pounds of sugar and 23.2 gallons of molasses from each ton. The laboratory work under the direction of Dr. H. W. Wiley, in charge of Prof. E. A. von Schweinitz, assisted by Mr. Oma Carr, has been most satisfactory. The information gained through their labors will prove very interesting and valuable to all friends of this industry.

I am well satisfied no well-regulated sugar works can be successfully operated and the best results obtained unless a complete chemical control of the every-day work prevails.

The following facts may not be out of place: This enterprise was no exception to those preceding in respect to starting late in the season, after the crop was planted, as it were. Less than three months intervened between the placing of orders for the machinery and the date of ripening of the first planted cane. The factory was two weeks in starting, and the other end of the season shortened by burning of the boilers November 4, leaving 75 acres of most excellent cane that was rich in sugar.

Gypsum had a most disastrous effect upon the boilers; frequent stoppages of work were required to clean them. By reason of excessive scaling of boiler shell and tubes the efficiency of the boilers was greatly reduced.

The following figures relative to this plant were taken from the books of the company and are reliable:

Cost of sugar-works plant	$44,547.72	
Less cost of water-works plant	6,000.00	
		$44,547.72
	38,547.72	
Donation city water-works bonds	12,800.00	
Received from United States Department of Agriculture	10,000.00	
Farmer's stock for cane paid in	4,500.00	
		27,300.00
Cost to present owners		17,247.72
Cost of labor	5,896.02	
Less labor on water works	1,500.00	
		4,396.06
Cost of fuel		3,096.33
Cost of cane		5,980.00
Cost of incidentals, barrels, etc		1,364.37
		14,836.72
100,000 pounds sugar, at 6½ cents		6,500.00
100,000 pounds sugar, 2 cents, State bounty		2,000.00
36,000 gallons molasses, at 12 cents		4,320.00
6,000 bushels seed, 50 cents (estimated)		3,000.00
		15,820.00
Gain		983.28

Five thousand dollars were paid to railroads for freight transportation. The cost for coal and labor to handle 1 ton of cane is $2.50; much coal was used for testing machinery, water-works, etc. Profit per ton over cost of production, 33 cents. Taking the season as a whole the plant was operated at less than half its capacity with no decrease in cost of labor. Fully 150 tons could have been worked with the same labor and an increase of 20 per cent. of fuel, making the value per ton of cane worked over cost of production $1.62, or $243 per day.

For working a 200-ton plant costing, perhaps, 20 per cent. and fuel 25 per cent., would show value of product over cost of production of $3.60 per ton, or $720 per day.

These yields are based upon results of this season's work—60 pounds of sugar and

16½ gallons of molasses from each ton, which certainly is 20 per cent. less than may reasonably be expected by the use of good water.

The average quality of sugar as placed upon the market from these works was equal to the best in purity, but stained slightly by contact with black molasses; it has a hard, firm, medium-sized, well-cut grain, was dried thoroughly, and, unlike all fine-grained sorghum sugars heretofore produced, does not cake or become hard in the barrel. It stands next to granulated in price and sweetening power, the jobbers selling at 6¼ cents per pound more of this sugar than all yellow sugars combined. Confectioners appreciate its sweetening power. The molasses was very dark in color, sharp and bitter to the taste, classed but little better than black-strap; with pure water the quality should be improved and the selling price increased to 18 or 20 cents per gallon.

The Department of Agriculture, under the direction of Dr. H. W. Wiley, who first advocated and practically applied the process of diffusion to the manufacture of sugar from sorghum, has made it possible to secure practically all the sugar in the juice, this being the first and greatest step towards the establishment of the industry; the next greatest and scarcely less important step still awaits a solution. I refer to the clarification of sorghum juices. The methods now employed for this purpose are borrowed from the sugar-cane work of Louisiana, being merely the addition of lime and removing what scums appear on the surface. Analysis shows the amount of sugar in each ton of cane, averaging the whole season, to be 249 pounds; the glucose would hold in solution 66 pounds, leaving 183 pounds available did not other solids, as gums, starch, coloring matter, etc., also restrain 1.4 times their equal of sugar from graining, until a possible yield of 100 pounds or less from each ton of cane is our best work. Must we stop here and permit the loss of one-half or more of the sugar found in the cane? The task is not an easy one, as the many know who have considered it even briefly, but its importance and necessity demand that we sit not idly by. The people of the whole southwestern portion of this State, to my personal knowledge, are enthusiastic upon the question of sorghum sugar; a failure any season to grow good sorghum is not recorded. The establishing of sugar works would bring under cultivation lands now considered of little value except for growing sorghum, and, fortunately, will produce a sorghum of the very best quality for producing sugar.

These facts are fully appreciated, and every town, many without water and others without railroads, aspires to the possession of sugar works.

Daily during the working season committees, delegations, and individuals visited the sugar works, leaving full of confidence in the work.

A number of factories could be erected in this section next season if experienced men could be found to operate them.

MR. DEMING'S DIRECTIONS FOR RAISING CANE.

Much depends on a good stand from the first planting. No filling in will be allowed. If necessary to replant any portion it must be replowed, cultivated, or listed over. The field should first be cleared of all trash, such as stalks, weeds, and bunches of grass. This is best done by raking and burning. Unless a lister is used a good seed bed, such as for wheat, should be provided, and the seed deposited in fresh, moist earth, deep enough to insure moisture, yet not beyond the sun's warmth. This varies from one-half inch in depth on heavy clay soils to 3 or more inches on light, loose, sandy soil.

It is essential that the seed be planted at an even, uniform depth to insure its coming up and ripening early, and the seed must under no circumstances be dropped or covered by hand. For loose sandy soils a lister is a good planter. A good garden drill may answer, and under some circumstances a forced wheat drill, having all the holes, except the two next the outside ones, closed, but for a prepared seed bed a regular two-horse corn-planter, with or without a drill attachment, gives the best result, planting at a uniform depth, and the wheel firming the soil about the seed, causing it to germinate and grow more rapidly with a better start of the weeds. Unless the planter has broom-corn plates, which are the best, the holes in the corn plates should be partially closed with lead, babbitt, cork, or leather, until they admit of the passage of not more than four or five seeds at each movement of the plate. A slight excess of seed should be planted, and the hoe used to properly clean it out. This should be done invariably before the cane is 4 inches high. Good soils will produce a stalk of cane for each 4 inches of row space. When the rows are 42 inches apart, two stalks should be allowed a space of 10 inches, three stalks 18 inches, four stalks 30 inches, six stalks 42 inches, and never more than six stalks in any one bunch, no matter how spaced.

Foul land is easiest tended when planted in checks, and all lands so planted pro-

duce more sugar but a smaller tonnage than when planted in drills. The cultivation should be merely upon the surface, to avoid cutting and otherwise disturbing the roots, checking their growth, and inducing a growth of suckers to sap the parent stalks and retard their development.

All that is required is to keep the grass and weeds in check, and all cultivation should cease when the joints appear, as any interference with the roots at this time results most seriously. One well-matured stalk will grow on the space occupied by two small ones, is as heavy as six small ones, and contains more juice sugar and less impurities in proportion to its weight. The seed and leaves are less than 25 per cent. of total weight of the large stalks, while with small canes the loss from this source may reach fully 50 per cent.

To plant cane upon new ground the turned sod should be quite thin, but evenly and smoothly laid. The seed should be planted with a two-horse corn-planter, provided with a rolling coulter to cut and not displace the sod, depositing the seed just underneath the subsoil. The sod acts as an excellent mulch to retain moisture and prevent the growth of grass and weeds, no cultivation or further attention, except thinning, being necessary until harvest time. A good practice for planting cane upon old ground is to plow the land at any time during early spring, but do not harrow. At planting time take a two-horse cultivator, place three small shovels upon each beam, spread and fasten the beams so that the shovels will work up a space for two rows, each 4 inches deep and 12 inches wide. Let the planter follow soon, depositing the seed in the center of this worked-over space. There will be no weeds or grass for 6 inches upon either side of the plants, and the cultivator will care for the space between the rows. Cane deteriorates very rapidly when cut, lying on the ground in bunches, exposed to the sun and drying winds, a few days of such exposure changing the sugar into glucose. Cane should be delivered the same day as cut, the only exception to this rule being to cut and load on the wagon the evening before what can be delivered early the next morning.

Next to the importance of properly thinning the canes, the necessity of having well-matured, freshly cut, promptly delivered cane is the most important point connected with the agriculture of this business.

Instructions for converting an ordinary hay-rack into a cane-rack will be furnished by the cane agent. Each wagon must be provided with two ropes, each three-fourths of an inch in diameter and 35 feet long, by which the cane is unloaded. The cane must be loaded so the tops project over the right side of the rack, facing the team.

ABSTRACT OF REPORT OF E. A. V. SCHWEINITZ.

CONWAY SPRINGS, KANS.

The results of analyses of whole canes are recorded in table No. 1. The canes were topped and stripped, and the juice expressed by means of a small hand-mill. The average amount of sucrose in the juice was about 2 per cent. higher than the average of any crop heretofore worked. The highest per cent. was found in sample No. 162, taken from a load of Sterling Orange. The lowest percentage of sucrose was noted in two samples of mixed Amber and unripe Orange on September 4 and September 10. The best samples taken during the working season were Nos. 27, Amber, 352, Orange, and 374, Link's Hybrid. The Amber cane after being cut, if left lying for any length of time, deteriorated rapidly, as shown by the analysis of No. 26.

The percentage of moisture in the cane during the month of October decreased rapidly, and the same quantity by weight of cane yielded only about one-half the weight of juice given earlier in the season. The dryness of the cane was also noted by the farmers, as their loads lost several hundred pounds as compared with the same sized load during the first part of the work. It may also be noted that the cane was very pithy. On an average one out of every five stalks contained little or no juice, and a large amount of fiber. The cane cut during October, a great quantity of which was left lying from two to three days at a time on account of delays in working, did not deteriorate to any great extent. The dryness of the cane again probably explains this.

After the factory stopped, a number of samples of cane was taken for the purpose of determining the condition of the still outstanding crop.

Samples Nos. 382 and 388 gave the highest result of the season. Another sample, No. 383, from a field which the cane-grower claimed was the poorest out, showed a high percentage. No. 378 was from a field of second growth from stubble. On November 4, some 25 tons of cane were left on the rack. One lot was selected and analyzed, some of it put into a silo. A sample of the remainder tested four days later showed that there had been no deterioration in the cane, as can be seen from

analyses Nos. 386 and 391. This cane had been exposed to heavy frost, snow, and thaw.

Cane taken from the field on November 7, and again from same field November 12, showed but little deterioration.

The average percentage of sucrose in the mill juices from the fresh chips is .3 per cent. higher than that recorded in the average of the whole canes. This is explained by noting several very low percentages of sucrose in some of the samples of whole cane, without a corresponding low percentage in the chips.

Here it may be noted that in taking samples of fresh and exhausted chips, as also of diffusion and clarified juices, care was taken to secure comparative samples. The battery consisted of 16 cells, but only 12 of these were in the circuit at one time. The fresh chips were taken from these 12 cells and the exhausted chips from the same. The juices were sampled as they ran into the defecators, care being taken to secure those corresponding to the fresh chips. The samples of semi-sirup were taken as a rule once every twelve hours, and correspond approximately to the juices analyzed. For the most part two sets of samples were taken, one in the morning and the other in the afternoon.

The lowest sucrose and highest glucose were recorded at the beginning of the season. The highest sucrose of the season was noted on October 15, and the lowest glucose on October 26.

The average percentage of sucrose for October was 13.22 and glucose, 2.07. From September 26 to the end of the season the mill juices appeared to be unusually rich. The average for October was .8 per cent. higher than the average for the entire season. This is 2.88 per cent. higher than the average at Fort Scott in 1887. As noted in connection with the whole canes, the dryness may partly explain this, but the location and soil of Conway seem to be especially adapted to the growth of sorghum. It is further south than any other point in Kansas where sorghum has been grown, and the season appears to be longer and better than in eastern Kansas.

The mean of sucrose in diffusion juices is higher than the mean at Fort Scott in 1887, but considerably lower than would be expected from the analyses of the chip juices. The difference may be accounted for either by the dryness and pithiness of the canes, as just mentioned, or by inversion in the battery. In order to prevent inversion, if any, carbonate of lime was used in the battery for a time. Although the acid was neutralized to about the same extent as at Fort Scott, apparently inversion was not prevented. In place of carbonate of lime a number of experiments were made with caustic lime. The lime was distributed upon the chips as they passed from the macerator to the battery by means of a roll, about 1¼ pounds of lime being added to each cell.

The object was to add just so much lime to the chips that 100 c. c. of the juice when in the clarifiers would require about 5 c. c. of $\frac{N}{10}$ alkali to neutralize it.

The highest per cent. of sucrose for the season in the diffusion juice was noted September 29, 10.02 per cent., being 2.30 per cent. above the average. The corresponding mill juice for the same date was 14.92 per cent. sucrose, 2.5 above the average, showing that fair comparative samples had been secured.

The average during October was 8.59 per cent. sucrose, 1.74 per cent. glucose, better than the results obtained at Lawrence, La., bearing in mind the fact that the sugar cane has less glucose. The purity of the diffusion juices was lower than that of the mill juices from the chips. This is due probably to inversion in the battery.

Record was kept during the entire season of the amounts of sucrose and glucose left in the chips. The highest percentage of sucrose in the mill juices from these was noted at the end of the season, November 2, being 2.91 per cent. The average extraction for the entire season was 88.72 per cent. of the sugar in the cane. This is a poor extraction, being fully 4.1 per cent. lower than the extraction at Fort Scott in 1887. The average dilution for the season was 11.55 per cent. From the first of the season to October 15, 160 gallons were drawn off each time; from that date till the close of the season 180 gallons. Each cell held 1,400 pounds chips. Deducting 10 per cent. for fiber we have 1,260 pounds juice in each cell.

Average weight of juice drawn from first of season to October 15 . pounds . .	1,349.00
From then till close of season . . . do . . .	1,512.00
Mean Brix from September 6 to October 15:	
In mill juices	18.93
In diffusion juices	13.05
October 15 to Nov. 2:	
Mill juices	20.10
Diffusion juices	12.55
Dilution from September 6 to October 15 . . . per cent. .	6.50
Dilution from October 15 to close of season . . . do . . .	16.06

The poor extraction was due partly to the large chips furnished by the small cutters during a portion of the season, to the irregularity in working, but chiefly to the small quantity of juice drawn off; all points which might have been more carefully noted and the loss avoided. As the dilution, if moderate, is of small importance, the object should be to get all or as nearly all as possible of the sugar from the cane.

The water from the well proved upon examination to be highly charged with mineral matter, containing 318 grains to the gallon. This was chiefly gypsum, together with some little magnesium sulphate and sodium chloride. A 10-per cent. solution of sugar prepared with this water and evaporated to a thick sirup showed no more inversion than a solution of the same strength made up with distilled water and evaporated. The addition of acetate of lime to the solution had no inverting action.

The water gave particular trouble in the boilers, forming rapidly a heavy scale. The want of proper cleaning in the early part of the season caused burning of the boilers on November 4, and stopped the work. The latter part of the season the vapor water was run into a pond and used for diffusion purposes. This water was strongly acid, due to the decomposition of organic matter, and not much of an improvement on the well water. On account of the foaming it was difficult also to use it in the boilers.

In the few samples of masse cuite not enriched the proportion of sucrose to glucose was about the same as in the semi-sirups, showing that there was not any inversion in the strike pan.

The percentage of ash found in the masse cuite is 1.5 higher, and in the molasses 1 per cent. higher than the average found at Fort Scott in 1887. This we may fairly attribute to the large amount of gypsum in the water. After pond water was substituted for the well water, except on one or two days when lime in the battery was in excess, the corresponding percentage of ash was diminished.

The following is the record of the number of tons of cane worked, sugar and molasses made:

Total number of tons of cane passed over the scales, 2,991.

Of this 430.5 tons were Early Amber mixed with unripe Sterling Orange; 2,560.5 tons were chiefly Orange with a small quantity of Link's Hybrid. The estimated average tonnage per acre is 10. The highest tonnage 13.5 per acre. Twenty-five tons were left on the cane rack when work stopped, so that the actual number of tons of cane worked was 2,996, and tons worked for sugar 2,535.5. Tons of cane for molasses only, 430.5. Deducting 25 per cent. for leaves and seed we have 2,225 tons of cleaned cane.

Total number of cells filled from September 12 to close	2,730
Number of pounds of chips in each cell	1,400
Total number of pounds of chips in cells (1,860 tons)	3,722,000
Number tons cleaned cane from September 12 to close	1,901

Making a difference of 41 tons unaccounted for, some of which was thrown out by the fan and from the drag. The remainder can be attributed to lost records which were missing for several days' work.

YIELD OF SUGAR.

Total number of pounds of sugar	100,500
Gallons of molasses	36,000

There was left on hand at close of season one tank full of semi-sirup, equal to 600 gallons of molasses. This makes average yield of sugar per ton of field cane, estimated on the cane actually worked for sugar, as 39.2 pounds, and on cleaned cane 52.8 pounds per ton. The quantity of molasses made per ton of clean cane was 14. Or estimating the sugar on total number of tons of cane cut during the season we have 45.1 pounds per ton of cleaned cane. Two trial runs were made during the season. The first 46.9, tons, gave 3,986.5 pounds sugar and 9,580 gallons molasses, equal to 85 pounds sugar and 20 gallons molasses per ton. The second trial run gave 90 pounds sugar and 16 gallons of molasses per ton on a run of 60 tons.

During the season there were lost by carelessness 4,800 gallons of semi-sirup and 7,200 gallons of juice, corresponding to about 100 tons of cane. The battery soured twice and was drawn off twenty-eight times, causing a loss of one hundred and ninety-two cells of chips of 1,400 pounds each, equal to 134 tons of cane. Deducting, then, 234 tons from the number of tons worked for sugar we have 1,667 tons of cleaned cane with an average of 60.2 pounds sugar per ton.

From each ton it was estimated that 2 bushels of seed and 200 pounds of leaves were obtained. The seed was carefully hand-picked and thrashed, so that this product will prove very valuable.

The total number of days actual work, counting each day at twenty-two hours. was thirty. By that we mean that the number of hours during which the cutter actually worked would be equal to thirty days of twenty-two hours each. If a factory is substantially built, the machinery strong and every bolt in its place, there is no reason why there should not be a steady yearly run of ninety days full time. During the working season every hour's delay is so much money lost, and a sugar factory should run as smoothly as a grist mill. It is a question of practical mechanics which a good machinist can handle.

ABSTRACT OF THE REPORT OF A. A. DENTON AND C. A. CRAMPTON, STERLING EXPERIMENT STATION.

The experimental work which has been done at the Sterling sugar experiment station was wholly in the line of improving the sorghum plant with a view to increase the yield of sugar from sorghum canes, to obviate certain physical or outward faults of the plant, and to obtain varieties which are less variable in their yield of sugar.

It is probable that the extraction of juice from sorghum canes has nearly or quite reached its practical limit and that diffusion apparatus needs only to be improved in details of construction, which is more properly the work of machinists.

It is probable that the evaporating apparatus used in sugar manufacture, the triple effect, the vacuum pan, etc., will not soon be very greatly improved, for they are the result of many years of experiment by scientists aided by the most skilled engineers.

There remains, however, a very important and promising field for experimental work in the line of sugar manufacture, and that is the improvement of the sorghum plant upon which the sorghum-sugar industry depends for ultimate success. The importance and necessity of such work has been recognized by every one who has been engaged in the development of the industry, but very little has been actually done in that direction; the greatest attention has been devoted to the methods of extraction and manufacture, while the quality of the raw material has been neglected.

If improved varieties of sorghum were developed, as improved varieties of the sugar cane or of the sugar beet have been developed, a successful future for the sorghum-sugar industry in competition with the sugar-cane and the sugar-beet industries could be confidently assured.

In illustration of this disability which hinders the sorghum-sugar industry it is proper to recall the fact that the new beet-sugar factory erected this year in California imported beet seed from Europe at heavy cost, because there the sugar beet has been bred up and improved by many years of persistent effort by experts in that line, so that this European improved beet seed produces at once in California beets which contain from 12 to 15 per cent. of sugar. New sorghum-sugar factories have been built this season in Kansas, but they can nowhere procure similar improved sorghum seed, for the sorghum plant has yet to be developed and improved. As an instance of the necessity for the exercise of care in the selection of seed, the experience of two of the new factories this season may be cited. One of us visited the factories at Douglass and Conway Springs at the beginning of the season, about September 7; at the latter place there was great complaint of the quality of the early cane; seed had been obtained supposed to be pure Early Amber, but seed of later varieties, such as Orange, had been allowed to become mixed with it in considerable quantities, and the result was a field of cane of which the greater part was fully ripe and ready for working while a portion was still green, with the seed not yet out of the dough. It required entirely too much labor to separate it in the field, and when the cane was cut and brought to the factory the green cane lowered the average of the whole to such an extent that it was hardly fit to work for sugar. At Douglass about 100 acres had been planted for early cane with seed supposed to be Early Amber. As the factory was greatly delayed in starting up fears had been entertained that this cane was overripe and deteriorating. Examination showed this "early cane" to be not Early Amber at all, but the old-fashioned Chinese, a variety which, with us at least, did not attain its maximum of sugar content until quite late in the season. Had the factory gotten into operation by the middle of August, as they expected, they would have found their "early cane" entirely too green to make sugar.

THE ORIGIN OF THE EXPERIMENTAL WORK AT THE STERLING SUGAR EXPERIMENT STATION.

In the spring of 1888 the Sterling Sirup Works planted all the varieties of sorghum which, with the time and means at their command, they could procure in this or in

foreign countries, in an experimental field under as similar conditions as possible, in order to enable them to compare the qualities of the canes of the numerous varieties with a view to selecting the best varieties for future cultivation. They had in mind a similar experimental plantation in Jamaica, where 60 to 70 varieties of the sugar cane have for many years been grown in order to select the varieties which were best suited to the West Indies;* the result of which is shown by the fact that an improved variety of sugar cane, which is sometimes called "Jamaica" because it was grown at and introduced by the Jamaica experiment station, is now giving an extraordinary yield of sugar in many places. They were induced to undertake this experimental work by the necessities of their business. In the past seven years they have produced each year from 500 to 700 acres of cane, and have manufactured the crop. Each year they have planted the common varieties, and also varieties new to them which they could readily procure. The selection of better varieties and the improvement of the quality of the canes is a matter of importance to them, as it is to all others who are concerned in the sorghum industry.

It appeared to the Sterling Sirup Works that the first step to be taken in improving the sorghum plant was to collect as many varieties as possible from all localities where sorghum is grown, to acclimate them and practically test the numerous varieties in all the points which constitute a good variety of sorghum.

It is now to be regretted that a much more extended search was not made in this and in foreign countries for other rare and unknown varieties; but they then regarded this year's work as only the beginning of a private research which would continue for some years.

THE NECESSITY FOR IMPROVING THE SORGHUM PLANT.

The sorghum plant is adapted to large areas of the country which are not adapted to the production of sugar from the sugar cane or from the sugar beet. It is especially adapted to the dry climate of the Great West. Its cultivation is suited to the habits of the farming population. When the sorghum plant has been successfully developed and improved as other sugar-producing plants have been, the sorghum-sugar industry will prosper and will employ capital and labor in producing the sugar which we now import.

THE FAULTS OF THE SORGHUM PLANT.

The sorghum plant is sometimes a good sugar-producing plant, sometimes it is merely a sirup-producing plant. This variability in the chemical composition of its juices is what might be expected from a plant which has not yet been bred up to fixed types of excellence by long-continued selections of seed from the finest plants of the best varieties.

In this connection it is interesting to note that in 1744 the chemist Marggraff was able to extract 5 per cent. of sugar from the beet; fifty years afterward the chemist Achard was able to extract but 1 per cent. of sugar from the beet, and the eminent chemist Sir Humphrey Davy published positive assertions that beet sugar could not be made profitably, and that beet sugar was not fit for use. Sixty-five years after Marggraff had extracted 5 per cent. of sugar from the beet, the beet-sugar factories realized only 2 per cent. of sugar from it. These facts seem to indicate that the sugar beet was variable until the plant had been developed.

Besides the variability of the sorghum plant there are other faults which pertain in greater or less degree to the different varieties. Some varieties are long and slender reeds with heavy seed tops and the canes are liable to lodge and tangle in storms. This fault greatly increases the difficulty of harvesting the canes, and the "down" or lodged canes are also inferior in saccharine value.

Some varieties "tiller;" that is, one root produces several canes just as one grain of wheat produces several stalks. This habit is injurious because the secondary canes ripen at different periods, and in harvesting large fields of cane it is impossible to avoid mixing overripe, ripe, and unripe canes. Some varieties have a fault of producing false or secondary seed heads. As soon as the cane approaches maturity, and often before that period, it forms two or more new seed heads which rapidly develop; this delays the ripening of the cane and lessens the yield of sugar. Some varieties, as soon as fully mature, produce offshoots from each joint of the canes and also offshoots from the roots, and the sugar in such rapidly disappears. Some

* Analyses of samples of these different varieties from a collection exhibited at the New Orleans Exposition in 1885 were made by C. A. Crampton, at the sugar laboratory of the Department of Agriculture in its exhibit. The results of these analyses were published by Professor Morris, in the *Jamaica Official Gazette*.

varieties rapidly deteriorate in the quality of the juice as soon as they are ripe and allow little time to manufacture the canes. Some varieties mature very small seeds and these produce plants which are weak and slow-growing in the first weeks of their existence and are kept clear from the more vigorous weeds with greater difficulty than the stronger plants which are produced by the larger seeds.

Some varieties have very impure juice and some have strongly acid juice. Some varieties give light yield of cane, light yield of juice, and light yield of seed. Some varieties obstinately retain the glume or the envelope of the seed grains so that it can not well be separated by ordinary means. Analyses seem to show that the clean grain of sorghum seed is practically equal in value to corn as food for stock, but the adhering glume or envelope contains tannin, which is injurious, and some varieties contain much of this substance and some but little. Some varieties mature so late that they give but little time to manufacture the canes before frost.

THE FAULTS OF THE SORGHUM PLANT AND OF THE SUGAR BEET COMPARED.

The sugar beet contains mineral substance which lessens the yield of sugar. As a rule these mineral substances in the juice vary inversely as the sugar varies; that is, the greater the percentage of sugar the lower the percentage of mineral substance.

Sorghum contains glucose in the juice, and this lessens the yield of sugar. As a rule the percentage of glucose in the juice varies indirectly as the percentage of sugar varies; that is, the greater the percentage of sugar the less the percentage of glucose.

The beet has also physical or outward faults; it is a biennial plant; it stores sugar the first season and produces seed the second season. The sugar beet often goes to seed the first season and such beets are worthless for sugar manufacture.

Sorghum is an annual plant. It produces sugar and also seed in one season; and when it has produced its sugar and its seed it often attempts a second crop of seed, and this lessens the yield of sugar.

The sugar beet sometimes makes a "second growth;" sorghum also sometimes sends out offshoots from every joint and offshoots from the roots. The sugar beet is sometimes hollow; sorghum canes are sometimes pithy and contain but little juice.

The sugar beet is sometimes attacked by the "brown penetration," a discoloration which lessens the yield of sugar; sorghum canes sometimes have brown or red spots in the interior of the canes.

The sugar beet often had faults of form; it had forked roots making harvesting the beets and cleaning them from dirt more difficult; sorghum also has faults of form.

CAN THE SORGHUM PLANT BE IMPROVED?

Judging by all analogies the sorghum plant can be very greatly improved by intelligent and long-continued selection. Stirpiculture in the animal kingdom has given us the Cotswold sheep, the Poland-China hog, the Jersey cow, and the Norman horse. In the vegetable kingdom it has given us the Peabody corn, the Zinfandel grape, the Lapice sugar cane, and the Klein-Wanzleben sugar beet. It has been truly said, "Wherever and whenever plant selection of the best for seed has been long continued wonderful results have been obtained." Darwin said: "Let any common plant, even a roadside weed, for instance, be grown on a large scale and let a sharp-sighted gardener select and propagate slight variations, and see if new varieties do not result." Knauer started with a variety of the sugar beet which contained but 11 per cent. of sugar; he improved it by selecting the best for seed until he produced the "Imperial" variety which contained 16 per cent. of sugar. Deprez et Fils, by selection of seed from the best roots, produced three varieties which contained from from 14 to 16 per cent. of sugar. Vilmorin, the celebrated horticulturist of France, created the "Improved Vilmorin," improved in form and in yield of sugar. There are no apparent reasons why the sorghum plant may not be improved by diligent use of similar methods.

THE METHODS OF IMPROVING THE PLANT.

The principal methods of improving the plant may be stated as follows:

(1) By growing and testing all known varieties and selecting the most promising.
(2) By hybridizing or crossing these varieties.
(3) By preserving "sports" or variations.
(4) By selecting seed from the finest individual canes of each variety.
(5) By improved methods of cultivation.

All of these methods have been practiced to a greater or less extent in the work at this station, and the results will be set forth in the order given above. It must be remembered, however, that the results accomplished in this direction by one season's work can be at best but a mere beginning. To attain the end desired in the improvement of the plant, the continuation of such work over a series of years is indispensable. If this season's work and the methods pursued will serve to point out the necessity and importance of this line of investigation, and, in general, the manner in which it may be best carried out, a great deal will have been accomplished. It is hardly necessary to call attention to the desirability of following up the system of development thus opened up; and it is to be hoped that opportunity may be afforded the Department in the future to carry out this work, which promises to be of the greatest value to the sugar industry.

I. Experiments in Growing Different Varieties of Cane.

It is probable that all varieties of sorghum are not equally well adapted to all localities where sorghum is grown. Some varieties have peculiarities which cause them to succeed best in certain places; the Early Amber, for instance, probably succeeds better and has more valuable qualities in Iowa than in Texas. There is an analogy in this with other plants. A Rhenish variety of the grape succeeds best in dry soil; a Swiss variety succeeds best in wet climates. Spanish varieties of wheat do not succeed in Germany; English wheat does not thrive in India.

To select the best varieties of sorghum for a given locality, it is necessary to grow all known varieties there and to select those which prosper best under its conditions.

It is not now easy to collect seed of numerous varieties of sorghum. The common varieties only are for sale by seed dealers; other varieties can only be found among distant cane-growers in this and in foreign countries. In collecting many varieties many duplicates of some varieties are obtained, because a single variety often has many names. This is natural in foreign countries, where different languages are used; but in our own country the same variety often has many names, which are usually derived from some peculiarity of the plant. This is also true of other plants. It is said that all the varieties of the sugar beet may be classed in four groups. There seem to be twenty-three principal varieties, which have several hundred names.

The varieties of sorghum often can not be distinguished by the appearance of the seed alone, or even by the seed-heads alone; they can best be classed by observing the growing canes. Varieties which have long been grown under very different conditions often vary enough from the usual type to be classed as subvarieties. The Chinese cane from Australia differs in some respects from the Chinese from Central America, and that differs in some respects from the Chinese of this country. These facts add to the difficulty of classifying the numerous varieties of sorghum. Sorghum is also grown in opposite hemispheres, and the proper season to collect varieties of sorghum in one country is not the proper season in another country.

VARIETIES GROWN AT THE STERLING EXPERIMENT STATION.

There were about 250 different plots of sorghum grown at this station. Of these 150 were crosses selected by Mr. Denton; the remaining 100 plots were planted with varieties presumably distinct, though more than one plot was planted of a few standard varieties from seed obtained from different localities. Of those supposed to be distinct varieties, however, though sent in under different names, many were found to be duplicates, showing minor variations perhaps, but not sufficient to entitle them to classification as distinct varieties. For instance, seeds of the well-known variety, the Red Liberian, were received bearing the names "African," "Sumac," "Clubhead," "Rio Blanco," etc.; samples of Honduras seed were named "Honey Cane," "Broom Cane," "Silver Top;" samples of Chinese cane seed were received as "New Sugar Cane" and "Sorghum Saccharatum." It will be seen in the following analyses that seeds of the same varieties received from different localities produced canes of quite different qualities. Thirty-six of the varieties proved to be non-saccharine, useful for forage purposes, but not containing enough saccharine matter to be of value as sugar-producing plants.*

In addition to most of the varieties grown in the United States, the list includes many obtained from Asia, Africa, and South America. The seeds of many foreign varieties were injured by dampness and by insects; from some of these not a single seed germinated.

*Of the non-saccharine varieties twenty were derived from China, eight from Africa, three from India, and five from this country. The seed from all these were carefully preserved, and will be distributed by the Department. Many will doubtless prove new and valuable acquisitions as forage plants.

COMPARISON OF THE VARIETIES BY ANALYSIS.

It is not an easy matter, as might seem to be the case at first sight, to make a comparison of different varieties by the analysis of juices from selected samples. In the first place, to make a fair comparison between varieties they should be taken at their maximum of maturity, and this is a point which can not be determined by any outward sign, but only by actual analysis. Then the difficulties of sampling cane can only be properly appreciated by one who is familiar with them. Add to these the difficulties of comparison, the obstacles in the way of always getting uniform conditions in the growth of the plots themselves; attacks of chinch-bugs in one plot and not in another; a sandy spot in one and not in another; imperfect germination of seed in one plot, causing a thinstand, while in another plot the canes stand close together; and it will be seen that the task of differentiation between varieties by growing them in plots and submitting the canes produced to analysis, is by no means an easy one. It is a very complex problem. One season's work should never be held conclusive. A variety may have been placed at a disadvantage, from some one of numerous possible causes.

In the work here the varieties were analyzed as often as possible, to avoid the error of having analyses of either unripe or over-ripe canes to compare with the analyses of other varieties at their maximum; the highest analysis obtained may be taken as the basis of comparison. The error of sampling was avoided as much as possible by taking good-sized samples, and by having them all taken by one and the same person.*

The errors arising from differences of growth were augmented, unfortunately, by irregularities in the time of planting, some lots of seed being received very late in the spring. The time of planting is noted with each plot.

In the following table the highest result attained by average samples from plots of the different varieties grown is given. In nearly all cases the sample showing the highest content of sugar gave also the best results in the other two essentials, viz. minimum of glucose and maximum of purity; but where this rule did not hold good the analysis which showed superiority in two essentials was inserted as the maximum analysis attained by the variety during the season.

Table showing maximum analyses of each variety.

Variety.	No. of plot.	Date.	No. of analysis.	Degree Brix.	Sucrose.	Glucose.	Coefficient of purity.
					Per cent.	*Per cent.*	
Swain's Early Golden	93	Aug. 24	3	18.03	12.88	1.92	71.44
Early Tennessee	102	Aug. 24	6	15.54	8.45	2.55	54.38
Whiting's Early Variety	234	Aug. 30	46	15.63	10.30	1.48	65.90
Black Amber	90	Sept. 7	120	12.88	6.50	3.14	50.47
White Amber	92	Aug. 24	....	18.03	12.99	1.84	72.05
Early Amber from New York	23	Aug. 24	4	18.10	13.70	1.12	75.69
Early Amber from Kansas	1	Aug. 25	8	17.54	13.18	1.07	75.14
Folger's Early Variety	249	Oct. 4	460	16.78	11.94	1.46	71.16
Chinese from—							
Central America	62	Oct. 15	593	17.37	11.79	1.35	67.88
New South Wales	215	Sept. 17	216	16.29	9.76	2.25	59.91
Africa	232	Oct. 8	508	17.98	12.46	1.44	69.30
United States	37	Oct. 8	511	19.00	13.23	1.40	69.63
White India	69	Oct. 9	531	17.67	13.07	1.02	73.96
White India from Louisiana	67	Oct. 5	474	16.33	11.90	1.26	72.87
Early Orange from—							
Kansas	84	Sept. 27	371	17.58	12.82	1.33	72.92
South Carolina	228	Oct. 5	467	18.76	13.62	1.72	72.60
Arkansas	87	Sept. 19	270	16.53	11.39	2.20	68.91
Louisiana	68	Sept. 15	601	17.90	12.90	1.13	72.07
Kansas Orange	49	Sept. 9	523	16.91	12.17	1.20	71.97
New Orange	88	Sept. 27	375	16.25	9.53	3.07	58.65
Late Orange from New York	89	Oct. 9	540	17.99	12.73	2.32	70.76
Medium Orange	235	Sept. 26	341	16.70	11.84	1.04	70.90
Red Liberian from—							
Missouri	72	Oct. 4	462	18.80	13.25	2.74	70.48
Texas	73	Sept. 27	367	19.92	14.76	1.84	74.10
Golden Rod	95	Sept. 5	99	14.35	6.96	4.48	48.50
Honey Dew	259	Oct. 22	660	18.10	11.92	2.62	65.86
Dutcher's Hybrid	98	Sept. 3	85	16.24	10.50	2.14	64.66
Link's Hybrid	....	Oct. 5	466	18.45	13.97	.82	75.72

* Mr. Denton did all the sampling himself,

Table showing maximum analyses of each variety—Continued.

Variety.	No. of plot.	Date.	No. of analysis.	Degree Brix.	Sucrose.	Glucose.	Coefficient of purity.
					Per cent.	Per cent.	
Price's Hybrid	101	Sept. 3	84	16.84	10.77	2.71	63.95
Planter's Friend	214	Sept. 30	418	20.50	13.83	1.66	67.46
Honduras from—							
Louisiana	64	Oct. 15	595	15.54	9.54	3.24	61.39
Texas	66	Oct. 22	654	15.15	9.84	2.72	64.95
Goose Neck	76	Oct. 22	664	17.20	11.38	2.59	66.16
Waubansee	230	Oct. 5	468	16.32	11.71	.91	71.75
White African	229	Sept. 22	305	17.20	11.10	1.67	64.54
Texas Red	....	Oct. 10	545	20.25	13.80	2.84	68.14
Unnamed varieties—							
United States	9	Oct. 15	610	16.26	11.48	1.29	70.60
South Africa	11	Oct. 8	513	12.20	6.55	2.65	53.69
United States	14	Oct. 19	646	18.60	13.84	.55	74.41
India	15	Sept. 26	347	18.64	12.87	.60	69.05
South Africa	16	Oct. 19	644	16.10	10.70	1.31	66.46
United States	22	Oct. 19	643	17.09	11.54	1.49	67.52
Africa	24	Oct. 6	497	18.42	12.72	2.86	69.06
Do	26	Oct. 8	515	16.31	11.48	1.60	70.39
Do	28	Oct. 15	608	16.20	11.38	1.41	70.25
United States	33	Sept. 26	351	16.97	11.85	1.41	69.83
Africa	36	Oct. 6	494	15.32	10.29	.63	67.17
Do	39	Oct. 5	480	17.20	12.79	.60	74.36
United States	44	Sept. 26	356	17.44	11.87	1.05	68.06
Do	50	Oct. 9	524	18.00	13.28	1.01	73.78
Do	51	Oct. 6	493	17.77	12.80	2.27	72.03
Do	53	Oct. 6	490	16.85	10.57	2.96	62.73
Do	57	Oct. 19	634	18.00	9.93	3.50	55.17
Do	61	Oct. 19	636	18.60	13.06	2.32	70.22
Average	....	....	....	16.79	11.69	1.85	69.62

These results are quite interesting as furnishing a means of comparison of the relative merits of the different varieties. The ten varieties which stand highest in each of the three essentials are given below, in the order of their value:

List of ten varieties giving best results.

No.	Sucrose.	Per cent.	Glucose.	Per cent.	Coefficient of purity.	Per cent.
1	Red Liberian	14.76	Plot No. 14, U. S	.55	Link's Hybrid	75.72
2	Link's Hybrid	13.97	Plot No. 39, Africa	.60	Early Amber	75.69
3	Plot No. 14	13.84	Plot No. 36, Africa	.63	Plot No. 14	74.41
4	Planter's Friend	13.83	Plot No. 15, India	.65	Plot No. 39	74.36
5	Texas Red	13.80	Link's Hybrid	.82	Red Liberian	74.10
6	Early Amber	13.70	Waubansee	.91	White India	73.96
7	Early Orange	13.62	Plot No. 50	1.01	Plot No. 50	73.78
8	Plot No. 50	13.28	White India	1.02	Early Orange	72.92
9	Chinese	13.23	Medium Orange	1.04	Plot No. 51	72.03
10	White India	13.07	Plot No. 44, U. S	1.05	Kansas Orange	71.97

These lists comprehend altogether eighteen varieties, of which four appear in all three of the lists, four on two, and ten on only one, as follows:

Plot No. 14	3	Plot No. 15	1
Link's Hybrid	3	Waubansee	1
Plot No. 50	3	Medium Orange	1
White India	3	Plot No. 44	1
Plot No. 39	2	Plot No. 51	1
Early Amber	2	Kansas Orange	1
Red Liberian	2	Planter's Friend	1
Early Orange	2	Texas Red	1
Plot No. 36	1	Chinese	1

From this it will be seen that four varieties combine in a high degree the three good qualities of a large percentage of sucrose, low content of glucose, and high purity of juice. Link's Hybrid and the unnamed variety No. 14 divide honors for the first place, both standing very near the top of the list in all three essentials. The former has always proved a good sugar producer, where it has had time to mature before frost. The Early Amber is noticeable for its high purity, five of the plots of its sub-varieties giving a purity of over 70; from this quality doubtless arises its superiority as a sirup-making variety. The low content of glucose in several of the unnamed varieties from tropical countries is remarkable, as most of them were not entirely mature before frost. It must not be lost sight of in comparing the varieties on the basis of the analysis that the outward faults of a variety may entirely overbalance its value as shown by analysis. The Link's Hybrid, for instance, which gives such good results on analysis, has a fault of form that almost destroys its practical value.

II. Experiments in Hybridizing or Crossing Varieties.—III. Experiments in Preserving Sports or Variations.

These two methods of improvement may as well be considered together, for in the present condition of the sorghum plant it is hard to draw the line between them. The different varieties which have become established cross so readily with one another that where variations occur, in a field of cane, for instance, it is often difficult to say positively whether it is a true sport, whether it is from one seed of a distinct variety accidentally introduced, or whether it is from a seed that had been cross-fertilized from a different variety. Doubtless both causes of variation obtain to a large extent, for the one is a natural consequence of the other; that is, on account of the readiness with which two individuals cross, a large number of varieties have been produced, and, as many of these are not well established or fixed, they exhibit a constant tendency to revert to original types, thus showing variations. Whether the wide variations shown in the different kinds of sorghum are due more to crossing or more to type variation is a question it is unnecessary to discuss here. It is sufficient to show that such capability for variation does exist. In the work done at this station no distinction could be made between variations produced by crossing and those which were true sports. As this season's work was only the beginning it was impossible to obtain true artificially-produced crosses, that is, variations produced by the careful cross-fertilization of two distinct and definite types. The plots called "crosses" were planted from seed heads obtained by Mr. Denton from various fields of sorghum, and were simply variations from the general type of the cane growing about them. In the great majority of these cases, the canes produced from this seed showed such well-marked reversions to two well-defined types that it was a pretty fair presumption that they actually did result from the cross-fertilization of those types; but of course such work should, in the future, be carried out upon known types, artificially cross-fertilized.

GENERAL OBSERVATIONS ON CROSSES.

Kolreuter says: "He who would produce new varieties should cross varieties." Darwin says: "In regard to the beneficial effect of crosses between varieties there is plenty of evidence." "The crossing of two forms which have long been cultivated implies that new characters actually arise some of which may be valuable and permanent." It would be superfluous to quote more, for Gartner, Herbert, Sageret, Lecoq, Naudin, and many other eminent experimenters speak of the wonderful vigor, size, tenacity of life, precocity, and hardiness of hybrid productions.

It is stated in "The Sugar Beet"* that "if a superior variety of beets be placed near another variety the result will be most advantageous, and it may be concluded from these experiments which we indorse that the resulting race will for the time being be richer in seed, and that the roots grown therefrom will contain a sugar content more regular, etc., than had existed in either."

In regard to the effect of crossing varieties it can be said that it seems to increase the vigor of the plants sometimes in a wonderful degree. The crossed canes are often much larger and taller, and often have much heavier seed heads than either parent form. A crossed cane is sometimes earlier, often later in maturing than either parent. Some crosses breed true to the new type from the start and show no tendency to reversion; but usually the first season the crossed seeds are planted some of the plants revert, some to one parent form, some to the other, and some are

* "The Sugar Beet," by Lewis E. Ware.

intermediate forms. If now seed of the type preferred is selected and planted again the new plants show less tendency to revert; by continuing the selection and throwing out varying forms, the new type is fixed and becomes a new variety. There is greater tendency to reversion in "violent" crosses between dissimilar forms than in crosses of allied forms. A cross may be slight or complete, in fact, there may be several crosses between two varieties. For instance, a fixed cross between the Early Amber and the Orange may resemble the Early Amber more; another cross between the same varieties may resemble the Orange more. Three canes taken from a plot of this last cross showed by analysis a higher percentage of sugar than any other in the season's work, with one exception.

ADVANTAGES OF SORGHUM OVER SUGAR CANE ON ACCOUNT OF THE EASE WITH WHICH VARIATIONS ARE PRODUCED IN THE FORMER.

Dr. Morris, formerly director of the Jamaica Botanical Gardens, where an experimental plantation of sixty to seventy varieties of the sugar cane is maintained, in an address before the London Chamber of Commerce said:

"It is well known that the sugar cane does not produce seed, and hence it is impossible to improve it by any process of hybridizing and crossing found so beneficial to other plants. New varieties amongst sugar canes arise generally in the form of bud variation. These occur very seldom, and possibly amongst thousands of acres not one cane will be detected which exhibits any well-marked characteristics. Planters, however, should be keen to notice any canes that show a departure from the types and should cultivate them separately. If the sugar cane were capable of being improved purely by cultivation and experimental processes like those which have improved the beet, this would be one of the most effective means of benefiting the industry."

GENERAL OBSERVATIONS ON "SPORTS" OR SPONTANEOUS VARIATIONS.

It is well known that new varieties sometimes suddenly and spontaneously appear in plants. They are created by bud variation. A peach tree suddenly produces a branch which yields nectarines. A plum tree which had yielded yellow plums for forty years produced a single bud which produced a new and valuable permanent variety, the red Magnum Bonum plum. The variations in the tropical sugar cane were entirely produced in that way, as has already been shown by the statements of Professor Morris, just quoted. In Mauritius a sugar cane of the ribbon variety produced two new canes, a green cane and a red one. This was considered an astonishing variation there. The causes of such variations are unknown. It is only known that they do occur, and that valuable new varieties sometimes suddenly appear. The history of some of the varieties of sorghum would seem to indicate, so far as it is possible to obtain accurate information of such matters, that they originated in this way. In Indiana, in a field of Chinese cane, a single cane ripened two weeks earlier than the other canes; this variation was preserved and named the Early Amber. It is the most widely known of all the varieties of sorghum. In the experimental field of this station there were growing Early Amber canes received from New South Wales, from Cape Town, and from many places, showing its wide distribution.

In New York in a field of Early Amber only one cane ripened before frost. This variation was preserved and named by us Whiting's Early Variety. It matures ten days earlier than the Early Amber. It seems to be a sport from a sport.

In Tennessee, in a field of Honduras a single cane ripened two weeks earlier than the other canes. This variation was preserved and was named Link's Hybrid. It is one of the best varieties of sorghum for sugar manufacture. It has been known to have as high as 19.25 per cent. of cane sugar in its juice by analysis.

WORK AT THE STERLING STATION ON CROSSES OR VARIATIONS.

It may be said of the work done here in this direction that, in the first place, it established positively, in the judgment of those in charge, *the fact of the very strong tendency of this plant towards variability.* This fact has, of course, been frequently noticed and commented upon heretofore, but as it seems very essential that it should be thoroughly and generally understood, we think it advisable to enter into an exposition of the evidence that was obtained to justify us in coming to the very decided conclusion we adopted upon this point. The plots which were planted as "crosses" at this station were in every case from single seed heads, selected by

Mr. Denton, and which were very carefully cleaned and thrashed, special precautions being taken to prevent any accidental mixture of seed from other sources. These plots were then, in every case, the product of a *single head*. They showed, in the majority of cases, the greatest variation among the individual canes.

This variability is well shown by a series of photographs taken by us, which were intended to be reproduced as illustrations of this report; unfortunately the fund provided for such illustrations was exhausted so that they had to be omitted. They represent a number of seed heads, all taken from the *same plot*, which showed striking variations from either parent type, as well as gradations running back to each. In a plot planted from a single seed head which was evidently a cross between the Orange and India, for instance, heads were selected which gave the greatest variations and gradations between the India type, with its white seeds and rather loose head, to the Orange, with its reddish-colored seeds and compact head. Another represents the range of variations between the Honduras and Red Liberian, two widely different varieties, with the small round seed of the Liberian type set closely on the sprangle top head of the Honduras. These photographs of the widely different types produced from a *single seed head* would convince the most skeptical of the great ease with which variations can be produced in sorghum.

LIST OF CROSSES.

The following list gives the number of the experimental plot with the probable parents of some of the crosses grown this season. Many plots are not included, as the characters shown by the canes did not distinctly indicate the origin of the variations.

No of plot.	Probable cross.	No. of plot.	Probable cross.
110	New Orange and Early Orange.	163	India and Orange.
111	Chinese and Liberian.	165	India and Amber.
112	Kansas Orange and Amber.	166	Do.
114	Golden Rod Cross.	167	India Cross.
115	Orange and Amber.	168	Do.
117	Kansas Orange and Amber.	171	Kansas Orange and India.
118	Liberian and Golden Rod.	172	New Orange Cross.
120	Amber and Kansas Orange.	173	India Cross.
121	Orange and White India.	174	India and Amber.
122	Orange and Chinese.	175	New Orange and Early Orange.
124	India Cross.	176	Orange Cross.
127	Do.	178	India and Orange.
128	India and Golden Rod.	179	India Cross.
129	Do.	180	Orange and India.
131	Orange and India.	181	Do.
132	India and Golden Rod.	182	India and Amber.
133	Kansas Orange and India.	183	India Cross.
134	Orange and Golden Rod.	184	Orange and India.
135	Early Orange and Amber.	185	Orange Cross.
136	Orange and India.	186	Orange and India.
137	India and Amber.	187	Do.
138	Do.	188	Do.
139	Orange and India.	193	Orange Cross.
140	Do.	194	Do.
142	India Cross.	195	Orange and India.
144	Orange and Amber.	196	Kansas Orange and India.
146	Kansas Orange and Golden Rod.	197	India Cross.
147	Do.	200	New Orange Cross.
151	Orange and India.	201	Do.
153	Kansas Orange and Early Amber.	202	India Cross.
154	Amber and New Orange.	204	India and Orange.
155	Orange Cross.	205	Orange Cross.
157	Amber Cross.	208	India Cross.
158	India and Orange.	211	Orange and India.
161	Kansas Orange and India.	212	Do.
162	India and Orange.		

ANALYSES OF THE CROSSES.

The following tables give only the selected analyses of single canes from the crosses. They represent about 700 analyses, only those containing the highest percentage of sugar, together with outward characters which entitled them to perpetuation, having been subjected to complete analysis.

Plots Nos. 153 and 184 gave probably the best results.

Analyses of single canes from Crosses.

No. of plot.	Date.	No. of analysis.	Degree Brix.	Sucrose.	Glucose.	Coefficient of purity.
				Per cent.	*Per cent.*	
109.....	Sept. 24	463	16.54	10.31	2.31	62.33
113.....	Oct. 10	1070	18.00	13.24	1.16	73.56
123...	Sept. 24	469	17.00	11.37	1.12	66.88
	Sept. 28	531	17.20	11.33	1.73	65.87
128.....	Oct. 10	1050	18.50	13.81	1.20	74.65
130.....	Oct. 10	1042	20.48	15.20	1.09	74.21
131...	Sept. 28	561	19.37	14.39	1.18	74.29
	Oct. 10	1059	20.00	14.48	2.63	72.40
132.....	Sept. 28	562	19.42	13.52	1.65	69.62
133.....	Oct. 11	1229	20.65	15.03	1.93	72.78
135...	Sept. 29	574	20.37	14.01	1.29	69.21
	Oct. 11	1218	21.13	16.33	.77	77.28
137...	Sept. 29	585	20.20	15.32	1.21	75.84
	Sept. 29	586	21.50	16.26	.81	75.63
138.....	Sept. 29	590	17.78	13.45	.69	75.65
142...	Sept. 29	613	20.78	15.54	2.33	74.78
	Oct. 10	1104	20.07	14.95	1.98	74.49
144.....	Sept. 29	621	19.28	14.68	1.10	76.14
146.....	Sept. 29	625	19.28	13.91	1.82	72.15
147.....	Sept. 29	603	15.87	11.61	1.69	73.16
148.....	Sept. 29	611	20.88	15.78	1.63	75.57
151.....	Oct. 11	1242	21.33	14.75	1.57	69.15
153...	Oct. 1	652	22.50	17.18	.58	76.36
	Oct. 11	1134	22.50	16.85	.91	74.89
155.....	Oct. 1	660	20.09	14.27	1.06	71.03
156.....	Oct. 1	664	18.62	12.15	4.56	65.25
159.....	Oct. 1	673	17.65	12.49	1.45	70.76
161...	Oct. 11	1277	20.70	15.40	.80	74.40
	Oct. 11	1287	19.70	14.89	.81	75.58
162.....	Oct. 1	691	18.85	13.84	1.24	73.42
163.....	Oct. 1	706	20.47	15.53	1.30	75.87
165...	Oct. 1	711	19.47	14.52	.53	74.58
	Oct. 12	1332	19.42	14.35	.69	73.89
166.....	Oct. 13	1491	19.78	15.04	.75	76.04
168.....	Oct. 1	738	18.60	14.98	.75	80.54
173...	Oct. 2	753	20.30	14.44	1.53	71.13
	Oct. 10	1667	21.20	14.28	1.90	67.36
	Oct. 12	1433	21.70	16.29	1.19	75.07
174...	Oct. 2	762	18.43	13.25	2.02	71.89
	Oct. 12	1412	21.60	14.86	2.65	68.80
175.....	Oct. 2	769	18.20	12.11	2.82	66.54
176.....	Oct. 2	776	19.93	14.81	1.76	74.31
178.....	Oct. 2	789	19.50	14.32	1.29	73.44
180.....	Oct. 3	811	20.00	14.14	1.05	70.70
182.....	Oct. 12	1357	20.28	13.96	1.53	68.84
184.....	Oct. 12	1344	21.78	16.40	1.01	75.30
208.....	Oct. 2	840	19.00	12.99	1.28	68.37
209.....	Oct. 2	833	20.03	14.43	1.17	71.99
212.....	Oct. 2	830	19.63	14.84	1.38	75.60
238.....	Oct. 9	1028	17.48	13.14	2.07	75.17
239...	Oct. 5	984	19.50	14.65	1.04	75.13
	Oct. 8	1010	20.14	15.24	1.55	75.67
	Oct. 8	1012	19.84	15.17	2.23	76.46

ANALYSES OF VARIATIONS IN STANDARD VARIETIES.

The following table gives some of the results of analyses of individual canes which were taken from the plots of some standard varieties, and which showed some *desirable* variation from the type of the variety. The variations chosen were in the line of the improvement of the variety. For example, the variations selected from the Honduras were individuals which ripened earlier than the rest of the plot; those of the Link's Hybrid were canes which showed more or less freedom from the faults of the variety. As with the crosses, the analyses given are the chosen ones of a large number of analyses, for none of the canes which showed simply an improvement in external characters were saved, unless they showed at the same time a good content of sugar and a high coefficient of purity. These will be reserved for planting another season.

Analyses of variations in standard varieties.

No. of plot.	Date.	No. of analysis.	Degree Brix.	Sucrose.	Glucose.	Coefficient of purity.	Remarks.
				Per cent.	*Per cent.*		
225-6.	Sept. 3	263	14.43	9.07	1.83	62.38	Honduras.
	Sept. 3	266	13.53	8.46	2.37	62.53	
	Sept. 17	306	17.84	12.14	.79	68.05	
	Sept. 17	313	18.72	12.59	1.18	67.25	
	Sept. 17	316	18.33	12.28	2.74	66.99	
	Sept. 20	338	18.28	12.70	2.65	69.47	
	Oct. 20	2118	20.00	14.90	1.02	74.50	
230...	Sept. 21	340	18.32	13.04	.99	71.18	Waubansee.
	Sept. 21	341	17.52	12.07	.81	68.89	
	Sept. 21	393	15.35	9.58	1.13	62.41	
234.....	Sept. 25	478	18.13	13.96	.91	77.00	Whiting's Early.
89......	Sept. 25	500	18.78	13.64	2.94	72.63	Late Orange.
68......	Sept. 28	521	17.21	14.42	.76	83.79	Early Orange.
67......	Oct. 3	893	19.20	14.04	1.37	73.13	White Mammoth.
232.....	Oct. 3	911	19.08	14.79	1.06	77.52	Chinese.
	Oct. 3	949	22.31	16.93	.55	75.89	Link's.

The unnamed plots also contained a great many interesting variations, selections from which are given in the following table:

Analyses of variations in the unnamed varieties.

No. of plot.	Date.	No. of analysis.	Degree Brix.	Sucrose.	Glucose.	Coefficient of purity.
				Per cent.	*Per cent.*	
9.......	Sept. 24	428	18.67	13.84	.80	74.13
33......	Sept. 25	509	19.48	13.17	2.61	67.61
37......	Sept. 22	396	19.60	14.26	1.04	72.76
45....	Sept. 22	406	19.60	13.92	.44	71.02
	Sept. 22	410	20.74	14.86	.37	71.65
46....	Sept. 21	360	20.60	14.83	.70	71.99
	Sept. 21	364	19.62	13.47	1.54	68.65
	Sept. 21	365	20.19	14.79	.76	73.25
	Sept. 21	366	20.75	15.14	.77	72.96
	Sept. 21	372	19.15	13.74	.59	71.75
	Sept. 21	373	19.92	14.67	.64	73.64
	Sept. 21	374	19.35	13.68	1.07	70.70
48....	Sept. 21	377	20.78	14.27	2.09	68.67
	Sept. 25	514	18.31	12.36	2.30	67.50
50....	Sept. 4	290	18.44	13.25	1.01	71.85
	Sept. 24	444	18.48	13.57	.95	73.43

IV. Experiments in the Selection of Seed from Individual Canes Showing a High Content of Sugar.

VARIABILITY OF SORGHUM CANES IN THEIR CONTENT OF SUGAR.

As might be expected of a plant which varies so much in the outward characters of its individuals, sorghum canes vary greatly in the chemical composition of their contained juices. Even in canes of the same varieties, showing uniform outward characters, and of uniform appearance and development, great differences will be found in the composition of the juice from individual canes; in fact, the variation in this respect seems much greater and more persistent than in the outward appearances of the plant. When the variety itself is not uniform, and the variations due to mixed races are added to the variations of the individuals, the most remarkable extremes are produced. This can be seen by examining the analyses of individual canes of crosses given in the section on experiments with crosses, from which the following table is selected to illustrate the possible differences between different

canes growing in the same plot. The canes were selected from a plot of Honduras which showed fairly uniform character, in the endeavor to obtain early ripened seeds of that variety, and probably some were not matured so well as others, though the seed from all was perfectly hard.

Polarization of selected canes from Honduras.

No.	Degree Brix.	Sucrose.
		Per cent.
1......	6.93	.20
2......	14.43	9.07
3......	13.53	8.46
4......	13.47	8.16
5......	10.47	4.31
6......	14.40	7.40
7......	11.85	5.78
8......	10.04	1.51
9......	11.65	5.24
10......	....	.10
11......	14.15	8.25
12......	17.05	11.41
13......	15.88	10.92
14......	15.34	9.33
15......	15.34	7.51
16......	15.54	6.50
17......	16.67	11.53
Highest		11.53
Lowest.............		.10

The following table shows the variation of individuals in a well-established and uniform variety. They were selected with this end in view from a remarkably uniform plot of Early Amber, and a particular effort was made to have the canes as nearly of the same size and general appearance, the same maturity, and the same conditions of growth as possible. All were taken from the same row.

Polarization of average canes from Early Amber.

No.	Degree Brix.	Sucrose.
		Per cent.
1.....	15.50	10.80
2......	15.70	12.02
3......	14.50	7.54
4......	18.00	12.78
5......	16.74	10.36
6......	14.74	8.58
7......	15.44	9.58
8......	18.44	13.25
9......	17.24	11.61
10......	17.44	11.99
11......	14.94	8.08
12......	17.74	12.71
13......	17.52	12.04
14......	17.32	10.53
15......	17.32	10.88
Highest		13.25
Lowest		7.54

While the difference is not so great as in the previous table it will be seen that there is a difference of nearly 6 per cent. of sucrose between the richest and poorest canes in fifteen samples.

DIFFICULTIES IN THE SELECTION OF SEED ACCORDING TO CONTENT OF SUGAR IN THE CANE.

It is much more difficult to select the best individuals of a sugar-producing plant than of plants raised for other purposes in which the relative merit of the individuals can be seen by outward appearances. There are no known reliable outward signs which indicate that a certain cane contains more sugar than the others. In a garden

one can select the finest vegetables, in the orchard the finest fruits, in the grain fields the finest ears of corn or of wheat either by the eye or by the weight or by very simple tests: but sugar is inside the canes, mingled with other substances. The weight of the canes or their appearance is not a reliable measure of the sugar which they contain. Handsome canes may contain but little sugar; canes inferior in appearance may yield sugar well. The sense of taste is not a reliable test, for the sugar in the juice is masked by other substances. A sugar cane which shows by analysis 12 per cent. of sugar tastes much sweeter than a sorghum cane which shows 15 per cent. The sorghum plant will be improved but slowly if selections of seed are made only by the size or weight or appearance of the canes, or by simple selections of the finest appearing seeds.

In two thousand analyses and polarizations of cane juice made at this station there were no reliable and constant outward marks observed by which the canes which contained most sugar could be selected. The degree of maturity was the only sign, and selections of the richest canes can not be made by that.

When the sugar-beet growers attempted to improve the sugar beet they met with the same difficulty. They were well aware that the hereditary principles which are known to apply to animals also apply to plants. They knew that the individual beets which actually contained more sugar than the others should be saved for planting.

But the characteristic points of beets which are rich in sugar vary so that they are not reliable guides in selecting beets for seed. Knauer invented a machine which separated beets into piles according to their weight in order to select the heaviest, not the largest, beets for seed. And beets were placed in a solution of salt water of a certain density; the beets which sank were saved for seed. These methods were not reliable. To Vilmorin is due the credit of introducing the methods by which the sugar beet has been so wonderfully improved. He observed that a cylindrical piece could be taken from each beet without injury to the plant. These sample pieces were separately tested to determine their value in sugar manufacture, and only the beets which were proved to contain more sugar than the others were saved for seed. To show the zeal with which the work of improving the sugar beet was done it is only necessary to say that at the Paris Exposition of 1878 there were twenty exhibitors who claimed to have produced improved varieties of the beet. Deprez et Fils, of France, had an agricultural laboratory with facilities for making two thousand analyses of beets daily. With the assistance of Professor Violette they produced three important new varieties of the sugar beet, which are known as "Improved Deprez" 1, 2, and 3.

It is evident that the sorghum industry should profit by this experience of the beet industry, and that sorghum seed should be saved only from individual canes which yield well in sugar.

METHOD OF WORK EMPLOYED AT THE STERLING EXPERIMENT STATION.

Owing to the pressure of work at this station the past campaign, and the attention given the crosses, the selection of seed from the best individual canes of the established varieties was not instituted until late in the season, and could not be carried out on the earlier varieties; the selections should properly be made, of course, at the maximum of maturity of the cane. The plan of work was as follows: A large number of canes were selected from the plot, care being taken that those selected should show no outward faults of form, and should be average canes in size and of good healthy appearance. A large number of such canes were brought into the station barn and laid out in serial order, the heads cut off, a label with number attached to each, and a corresponding number placed on a receptacle to contain the juice. Two men were kept busy turning the hand-mill, while a third kept the juices in proper order. As soon as the juices were obtained they were poured into hydrometer jars, and when they had stood long enough to permit of the escape of the air bubbles, their density was taken roughly with a spindle. If the reading did not come up to a certain standard, the juices and corresponding seed heads were rejected. The standard used depended upon the richness of the variety of cane from which the selections were made, being placed at 20° or even 21° Brix for very rich varieties like the Link's Hybrid. The few juices which passed the test were sent to the laboratory for complete analysis, and the corresponding seed heads carefully preserved. From the complete analyses, still further selections were made, so that ultimately a few seed heads were saved, showing great richness and purity of juice. From 500 to 1,000 canes could be tested in this way in a day. Some of the canes obtained by this method of selection were very rich in sugar. The following instances serve to show this:

A plot of Link's Hybrid, of which the highest analysis from average samples had

been 14.09 per cent. sucrose, gave by selection from about 500 canes four which went over 15 per cent. Another plot of the same variety, showing by analysis of an average sample 12.24 per cent. sucrose, gave by selection from 500 canes three which had over 16 per cent. sucrose in the juice. An average sample of a plot of Liberian cane gave 14 per cent.; 500 canes were taken from different parts of the plot, and one cane gave 17.59 per cent. sucrose in the juice, three gave over 16.5 per cent., and twelve over 15.5 per cent. An average sample of the Planter's Friend, a new variety from Australia, gave 11.63 per cent. sucrose; selections from 1,000 canes gave three which contained over 15 per cent. sucrose in the juice. Such instances might be multiplied, but sufficient evidence has been given to show the possibilities in this method of improvement. The selections have all been preserved, and can be planted and observed another year if means are afforded the Department for carrying out the work.

The following table gives the highest analyses obtained in each of five varieties by selection:

Highest analyses of single canes by selection from standard varieties.

Variety.	Date.	No. of analysis.	Degree Brix.	Sucrose.	Glucose.	Coefficient of purity.
				Per cent.	*Per cent.*	
Liberian	Oct. 17	1953	21.71	17.69	1.97	81.48
Early Orange	Oct. 18	2040	22.18	17.05	.67	76.87
Link's Hybrid	Oct. 18	2036	21.70	15.92	.69	75.38
Planter's Friend	Oct. 16	1831	22.00	15.55	.82	70.68
Chinese	Oct. 13	1508	19.68	14.71	1.25	74.75

V. Experiments in Improvement by Methods of Cultivation.

It is a rule in agricultural science that to obtain the best results the individual plants must be given the most favorable conditions possible for full development. In the effort to improve the sorghum plant methods of cultivation will play an important part. Very little attention has been paid heretofore to this subject, the cheapest and easiest methods being followed, and the sorghum crop has had about the same cultivation as is given to the corn crop. In the work at this station no very extensive experiments could be made on different methods of cultivation, but a number of practical points were evolved which may be stated as our views on the best methods to be followed without going into details as to the evidence upon which the conclusions were based.

It is desirable in growing cane for sugar manufacture that as nearly as possible all of the plants in one field should ripen at one time. If in one row there are some canes fully ripe and other canes immature, it will not be easy to harvest the canes at the time when each contains its maximum of sugar. It is a point of advantage to have all come up at the same time. This can best be accomplished by planting the cane on freshly-plowed land the same day the land is plowed and by being careful to cover the cane seed at a uniform depth with earth. This insures as uniform a start as possible for the canes, and while it may seem a trifling matter, it often materially affects the result.

After the young plants come up a serious problem arises, and that is, how to cultivate the plants, to pulverize and loosen the soil, and to destroy the weeds without injuring the roots on which the development of the plants depends. Great injury is done to the roots of canes when the cultivator works deep and close to the plants after they have attained considerable size. This injury is perhaps greater than most persons suppose. It appears to be proved by a very simple experiment. If the roots of a hill of cane are cut all around the hill with a spade at a distance of 6 inches from the canes to a depth of 6 inches from the surface when the plants are 4 inches high, and if this process is repeated once a week until the canes are 4 feet high, the canes thus treated will be found to ripen later and to be inferior in all respects. In wet seasons the injury is not so great as in dry, but injuries are caused to growing plants by the cultivator as with the spade.

To avoid destroying and mutilating the roots of growing canes it seems better to give deep and close cultivation while the plants and their roots are small, and when the first cultivation is given to use long and narrow shovels which work near the canes, and with a slow and steady team give close and deep and thorough cultivation before the rootlets are expanded sufficiently to be injured by such cultivation.

In the succeeding cultivations "shallow shovels," that is, shovels having such form that they do their work at and near the surface of the soil, should work near the plants, while deeper cultivation may be had at a distance from the plants which the roots have not reached. The form preferred in the experiments at this station is known as the "Eagle's Claw." It consists of eight small shovels which are attached to the beams of a two-horse cultivator, four shovels working on each side of the row of cane. The form of these shovels is such that they do not enter the soil deeply, they thoroughly pulverize all the surface soil and destroy weeds, and work close to the growing plants with little injury to the roots.

We have alluded to these points because we believe the yield of sugar is often materially lessened by injuring the roots of the canes. Mutilation of the cane plants above the surface of the soil is known to produce a lessened yield of sugar, and injuries to the cane plants below the surface doubtless decrease it also. Many cane growers as they "lay by" their cane crop or finish the cultivation, and see its deeply and closely cultivated canes free from weeds do not realize that while destroying the weeds they nearly destroyed their cane plants, and while working *for* their canes they were really working *against* them and against their yield of sugar.

VI. Miscellaneous Experiments and Results of Observations.

ANALYSES OF SAMPLES FROM ARKANSAS.

The capabilities of Arkansas as a sorghum-growing State have never been very extensively investigated. The Sterling Sirup Works received this fall a bundle of cane from one of the "prairie counties" of Arkansas, and the different samples were analyzed at the station with the following results:

Analyses of cane from Arkansas, sent to Sterling Sirup Works.

Variety.	No. of analysis.	Degree Brix.	Sucrose.	Glucose.	Coefficient of purity.
			Per cent.	*Per cent.*	
Texas Red	545	20.25	13.80	2.84	68.1
Honduras	546	20.25	3.68	8.47	18.
Chinese	547	18.25	11.05	5.24	61.
Orange	548	19.25	14.24	2.23	74.

As a general rule samples of sorghum sent from one point to another by express are so much inverted that the analyses are worthless; and then when samples of a few canes are selected by persons not familiar with the plant, the largest and finest looking canes are chosen, which generally give a lower per cent. of sugar than average-sized canes. In view of these facts the above analyses make a remarkably fine showing for the locality which produced the canes; the samples all consisted of quite large, fine canes, but still gave a good analysis. The sample of Texas Red was a tremendously large cane. The samples of Honduras and Chinese had evidently inverted slightly, the others very little.

Another lot of samples received by the sirup works from Thomas Lester, Stuttgart, Ark., consisted of the following varieties: Gooseneck, Honduras, and Orange. As the analysis showed all to be badly inverted, it is not worth while to give the results.

PROGRESS OF THE BEET-SUGAR INDUSTRY.

The interest in the manufacture of sugar from the sugar beet in this country is constantly increasing.

During the past season the Department distributed quite a quantity of sugar-beet seed to various parts of the country, and a number of samples grown by farmers in different localities has been sent to Washington for examination. The culture of the sugar beet has extended in the State of California, and in addition to the factory operated at Alvarado, the reports of which have been published in previous documents, a large factory has been established by Mr. Claus Spreckels and others at Watsonville, Cal. The corporation is known as the Western Beet Sugar Company, and has a capital stock of $500,000. The operations of the first year were very successful, and through the kindness of Mr. Spreckels I am enabled to

append a statement giving the résumé of the work done, expenses incurred, and amount and value of sugar made:

Recapitulation of the workings of the Western Beet Sugar Company's factory at Watsonville, Santa Cruz County, Cal., for the campaign ending December 19, 1888.

Sugar, freight from Watsonville to San Francisco		$2,936.55
Coal	total cost	17,267.00
Coke	do	1,658.93
Fuel oil	do	11,356.02
Wood	do	990.50
Lime rock	do	1,780.30
Sugar bags	do	1,740.34
Soda	do	12.39
Tallow	do	57.21
Expense labor, etc		21,091.27
(Beets) incidentals		2,575.82
Cost of beets		71,055.89
		132,522.22

Which is the cost of manufacturing 1,640 tons sugar delivered free on board in San Francisco.

We have received for 3,289,000 pounds sugar	162,454.70

Making cost of sugar $80.80 per ton of 2,000 pounds.

Profit	29,932.48

Beets consumed	tons	14,077
Sugar produced	do	1,640
Men employed		135
Time of run	days	61
Beets, average polarization	per cent	14.60
Beets, average sugar recovered	do	11.65
Sugar, average polarization	do	95.40
Sugar, average price	per pound	5.64 cents
Beets, average price	per ton	$5.04

No report has been received of the operations of the factory at Alvarado during the past season, and therefore I am not able to say whether or not the work was successfully conducted.

Mr. Fred Hinze cultivated an experimental plot of sugar beets at Douglass, Kans., during the past season. Considering the dryness of the climate and the high temperature reached during the summer, the results appear to be favorable. I am inclined to think, however, that the successful cultivation of the sugar beet for manufacturing purposes can not be looked for in such a climate as obtains at Douglass.

The analyses of the sugar beets at this station were made from time to time by my assistants at Douglass who had charge of the chemical work at the sorghum factory at that place. Following are the results of the work:

Date.	Brix.	Sucrose.	Coefficient of purity.
		Per cent.	
September 3	13.58	9.27	67.64
September 3	11.67	7.96	68.30
September 3	12.45	8.16	65.46
September 10	16.74	12.38	73.90
September 20	14.70	9.47	64.42
September 29	14.43	10.47	72.69
October 11	15.95	11.98	75.11
Highest	16.74	12.38	75.11
Lowest	11.67	7.96	64.42
Average	14.22	9.36	69.65

Great success also attended the growing of sugar beets in Nebraska at Grand Island. As will be seen by the following table, samples of these beets were analyzed by various chemists, and all found them excellent for sugar-making purposes.

Brix.	Sugar.	Coefficient of purity.	Brix.	Sugar.	Coefficient of purity.
	Per cent.			*Per cent.*	
*17.2	14.9	86.00	‡16.0	13.71	85.70
*18.9	16.1	85.00	‡17.1	14.2	83.00
*19.5	17.5	89.00	§16.3	13.10	80.40
*21.4	19.2	90.00	‖18.9	15.8	83.60
*19.7	16.7	84.00	‖18.2	15.20	83.50
*21.8	19.8	90.00	‖18.4	15.90	86.40
†18.8	16.4	87.10			

* Analyzed by Prof. William Huch, from Shoemingen, Germany.
† Beets harvested October 15, 1888, preserved in silo, analyzed January 2, 1889.
‡ Analyzed by Dr. Pauly, of Muhlberg, Germany.
§ Analyzed by Dr. Mueller, of Ottleben, Germany.
‖ Analyzed by Dr. Janke, Trendlébush, Germany.

Samples of these beets were also sent to the Department for analysis and entered as Nos. 6077 and 6078. The results of these analyses were as follows:

	6077.	6078.
	Per cent.	*Per cent.*
Juice extracted	56.16	54.70
Total solids in juice	18.40	18.80
Sucrose	15.38	15.75
Purity	83.59	83.77

As will be seen by the above analyses these beets were very rich in sugar, and if they could be grown in large quantities, which there is no reason to doubt, would indicate that in that locality the beet-sugar industry could be successfully established.

Another set of samples which had been harvested for three months was sent to the Department from Sturgis, Dak., and entered under No. 6162, a rose-colored beet, and No. 6163, a white beet. These samples were sent by W. C. Buderus, of Sturgis, Dak. On examination of these beets the following numbers were obtained:

	6162.	6163.
	Per cent.	*Per cent.*
Juice extracted	36.05	42.77
Total solids in juice	20.40	21.48
Sucrose	13.32	15.03
Purity	65.29	69.97

The low purity of the beets represented above was doubtless due to the fact that they had been harvested for a long time and no precautions taken to preserve them from deterioration. The analyses show that such beets could also be profitably used for sugar-making if worked up in a fresh state or preserved in proper kinds of silos.

The Department has had so many inquiries concerning the sugar-beet industry that the Commissioner of Agriculture has decided to issue another bulletin on this subject embracing the more important matters in bulletins already published, and which are entirely out

of print, and including the latest information accessible at the present time.

The coast valleys of California, large areas in Oregon and Washington Territory, parts of Nebraska, western and southern Michigan, northern Indiana, Ohio, and New York, and many portions of the New England States appear to be well adapted to the growth of a sugar beet rich in saccharine matter.

There is every reason to believe that the production of sugar from the sugar beet in this country will be vastly extended, and that beet sugar, in conjunction with sugar from sorghum and sugar cane, will be an important factor in the future sugar supply of the United States.